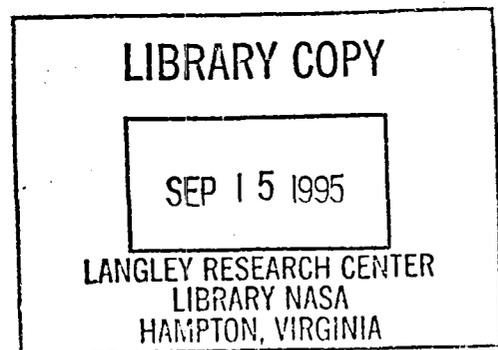




Debris/Ice/TPS Assessment and Integrated Photographic Analysis of Shuttle Mission STS-70

Gregory N. Katnik, Barry C. Bowen, J. Bradley Davis







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SHUTTLE MISSION STS-70

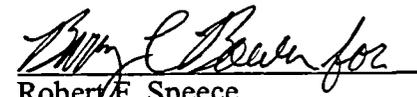
13 July 1995

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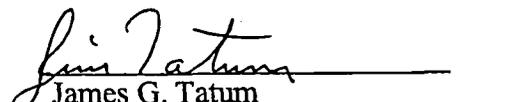

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TV-MSD-7



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FOREWORD

The Debris Team has developed and implemented measures to control damage from debris in the Shuttle operational environment and to make the control measures a part of routine launch flows. These measures include engineering surveillance during vehicle processing and closeout operations, facility and flight hardware inspections before and after launch, and photographic analysis of mission events.

Photographic analyses of mission imagery from launch, on-orbit, and landing provide significant data in verifying proper operation of systems and evaluating anomalies. In addition to the Kennedy Space Center Photo/Video Analysis, reports from Johnson Space Center and Marshall Space Flight Center are also included in this document to provide an integrated assessment of the mission.



Photo 1 : Launch of Shuttle Mission STS-70

1.0 SUMMARY

A pre-launch debris inspection of the pad and Shuttle vehicle was performed on 12 July 1995. The detailed walkdown of Launch Pad 39B and MLP-2 also included the primary flight elements OV-103 Discovery (21st flight), ET-71 (LWT 64), and BI-073 SRB's. There were no vehicle or facility anomalies.

The vehicle was cryoloaded on 13 July 1995. There were no Launch Commit Criteria (LCC), OMRS, or NSTS-08303 criteria violations. No IPR's were taken. Due to the ambient weather conditions at this time of year, there were no acreage icing concerns. There were also no protuberance icing conditions outside of the established data base. The Final Inspection Team specifically checked the woodpecker damage site repairs, none of which exhibited ice/frost formations, debonds, or material protrusions. The portable STI scanner showed no unusual or unexpected temperature gradients between the repaired areas and the adjacent acreage.

After the 09:41:55 a.m. (local) launch on 13 July 1995, a debris walk down of Pad 39B was performed. No flight hardware or TPS materials were found. There was no visual indication of a stud hang-up on any of the south holddown posts. All the T-0 umbilicals operated properly. Extensive damage occurred to the facility cable tray covers running along side the hydrogen cross country fill lines on the northeast side of the pad. Some of the concrete supports were also broken.

A total of 125 films and videos were analyzed as part of the post mission data review. No vehicle damage or lost flight hardware was observed that would have affected the mission. A large piece of aft skirt instafoam, approximately 18 inches long by 10 inches wide by 10 inches thick, stuck to the RH SRB aft skirt purge line as the vehicle lifted off holddown post #2. On-orbit crew handheld still photography showed no anomalies on the ET after separation from the Orbiter.

The Solid Rocket Boosters were inspected at Hanger AF after retrieval. The number of MSA-2 debonds on both frustums was average. The RH SRB BSM aft attach bracket adjacent to HDP #1 was missing K5NA to substrate.

A post landing inspection of OV-103 was conducted 22 July 1995 on runway 33 at KSC. The Orbiter TPS sustained a total of 127 hits, of which 9 had a major dimension of 1-inch or larger. Based on these numbers and comparison to statistics from previous missions of similar configuration, the total number of hits was slightly less than average and the number of hits 1-inch or larger was significantly less than average. The Orbiter lower surface sustained a total of 81 hits, of which 5 had a major dimension of 1-inch or larger. These numbers might indicate minimal problems with ET ice, failed woodpecker damage repairs, and intertank TPS divots during ascent.

Main landing gear tires and brakes were in good condition for a landing on the KSC concrete runway. However, four pieces of rubber from the nose landing gear tire were recovered at the 5500 foot marker. The tire was damaged by contact with centerline light cover #4-9 protruding 1/4-inch above the adjacent runway concrete. This particular cover, one of 298 on the runway centerline, is 3/4-inch steel, 12 inches in diameter, and secured with six 3/8-inch bolts recessed into U-shaped cutouts. Filler compound, placed between the cover and the runway concrete, has not been a debris problem. Recent inspections identified nineteen centerline light covers exceeding a 1/8-inch protrusion (program specification). Several plans to correct the problem prior to the STS-69 landing are currently being assessed.

Orbiter post landing microchemical sample results revealed a variety of residuals in the Orbiter window samples from the facility environment, SRB BSM exhaust, Orbiter TPS, and paints/primers from various sources. These residual sampling data do not indicate a single source of damaging debris as all of the noted materials have previously been documented in post-landing sample reports. The residual sample data showed no debris trends when compared to previous mission data.

2.0 PRE-LAUNCH BRIEFING

The Debris/Ice/TPS and Photographic Analysis Team briefing for launch activities was conducted on 12 July 1995 at 0830 hours. The following personnel participated in various team activities, assisted in the collection and evaluation of data, and contributed to reports contained in this document.

J. Tatum	NASA - KSC Chief, ET/SRB Mechanical Systems
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S. Reynolds	Rockwell LSS Systems Integration
J. Cook	THIO - LSS SRM Processing
S. Otto	LMSO - LSS ET Processing
M. Barber	LMSO - SPC Safety

3.0 LAUNCH

STS-70 was launched at 95:194:13:41:55.020 GMT (9:41:55 a.m. local) on 13 July 1995.

3.1 PRE-LAUNCH SSV/PAD DEBRIS INSPECTION

A pre-launch debris inspection of the launch pad and Shuttle vehicle was performed on 12 July 1995 from 0930 to 1115 hours. The detailed walkdown of Pad 39B and MLP-2 also included the primary flight elements OV-103 Discovery (21st flight), ET-71 (LWT 64), and BI-073 SRB's. There were no vehicle anomalies. Loose MLP deck bolts on the pedestals adjacent to HDP #3 and #7, and on an access door in the northeast raised deck area were annotated in OMI S0007, Appendix K for resolution prior to cryoload.

3.2 FINAL INSPECTION

The Final Inspection of the cryoloaded vehicle was performed on 13 July 1995 from 0425 to 0600 during the two hour built-in-hold at T-3 hours in the countdown. There were no Launch Commit Criteria (LCC), OMRS, or NSTS-08303 criteria violations. No IPR's were taken. Due to the ambient weather conditions at this time of year, there were no acreage icing concerns. There were also no protuberance icing conditions outside of the established data base.

Ambient weather conditions at the time of the inspection were:

	<u>T-3 Hours</u>	<u>T-0 Launch</u>
Wind Speed (knots):	04	03
Wind Direction (degrees):	314	044
Relative Humidity (percent):	89	82
Temperature (degrees F):	75	82
Dew Point (degrees F):	66	

A portable Shuttle Thermal Imager (STI) infrared scanning radiometer was utilized to scan the vehicle for unusual temperature gradients, particularly those areas not visible from remote fixed scanners, and to obtain a random sampling of vehicle surface temperature measurements to thermally characterize the vehicle. The scan also verified the integrity of 174 woodpecker hole repairs.

3.2.1 ORBITER

No Orbiter tile or RCC panel anomalies were observed. The paper covers on all RCS thrusters were intact. Typical ice/frost accumulations were present at the SSME #1 and #2 heat shield-to-nozzle interfaces. No anomalies were observed on the new Block SSME in the #1 position though liquid oxygen falling from the drain line reached the flame trench floor before completely vaporizing. An infrared scan revealed no unusual temperature gradients on the base heat shield or engine mounted heat shields.

3.2.2 SOLID ROCKET BOOSTERS

SRB case temperatures measured by the fixed STI radiometers ranged from 76 to 78 degrees F. In comparison, temperatures measured by the SRB Ground Environment Instrumentation (GEI) ranged from 76-82 degrees F. All measured temperatures were above the 34 degrees F minimum requirement. The predicted Propellant Mean Bulk Temperature (PMBT) supplied by THIO was 81 degrees F, which was within the required range of 44-86 degrees F.

3.2.3 EXTERNAL TANK

The ice/frost prediction computer program 'SURFICE' was run as a general comparison to infrared scanner point measurements. The program predicted condensate with no ice/frost accumulation on the TPS acreage surfaces after cryoload.

A three-man segment of the Final Inspection Team specifically checked the woodpecker damage site repairs, none of which exhibited ice/frost formations, debonds, or material protrusions. The portable STI scanner showed no unusual or unexpected temperature gradients between the repaired areas and the adjacent acreage.

The Final Inspection Team observed light condensate, but no ice or frost accumulations, on the LO2 tank. There were no TPS anomalies.

The intertank acreage exhibited no TPS anomalies. Typical ice/frost accumulation, but no unusual vapor, was present on the ET umbilical carrier plate.

There were no TPS anomalies on the LH2 tank. Light condensate, but no ice or frost accumulations, were present on the acreage.

There were no anomalies on the redesigned bipod jack pad closeouts. Two cracks, 4-inches long by 1/4-inch wide and 5-inches long by 1/8-inch wide, were present in the -Y ET/SRB cable tray forward surface TPS. The two-crack condition was assessed from a debris and ascent thermal environment standpoint and was found acceptable for flight per the NSTS-08303 criteria.

Typical amounts of ice/frost had accumulated in the LO2 feedline bellows and support brackets.

There were no TPS anomalies on the LO2 ET/ORB umbilical. Ice/frost fingers on the separation bolt pyrotechnic canister purge vents were typical.

Ice and frost in the LH2 recirculation line bellows and on both burst disks was typical. The LH2 feedline bellows were wet with condensate.

Less than usual amounts of ice/frost had accumulated on the LH2 ET/ORB umbilical purge barrier top and outboard sides. Typical ice/frost fingers were present on the pyro canister and plate gap purge vents. Ice/frost had formed on the aft pyro canister closeout bondline. No unusual vapors or cryogenic drips had appeared during tanking, stable replenish, and launch.

The summary of Ice/Frost Team observations/anomalies, which were all acceptable for launch per the NSTS-08303 criteria, consisted of three OTV recorded items.

3.2.4 FACILITY

All SRB sound suppression water troughs were filled and properly configured for launch (LCC requirement).

No leaks were observed on either the LO2 or LH2 Orbiter T-0 umbilicals, the GH2 vent line, or the Ground Umbilical Carrier Plate (GUCP).

The loose bolt on the film camera E-16 mount near the LH SRB exhaust hole could not be removed due to the presence of a nut on the inside of the housing. The bolt, which could not be torqued, was left wrench tight. The bolt will be welded in place after launch.

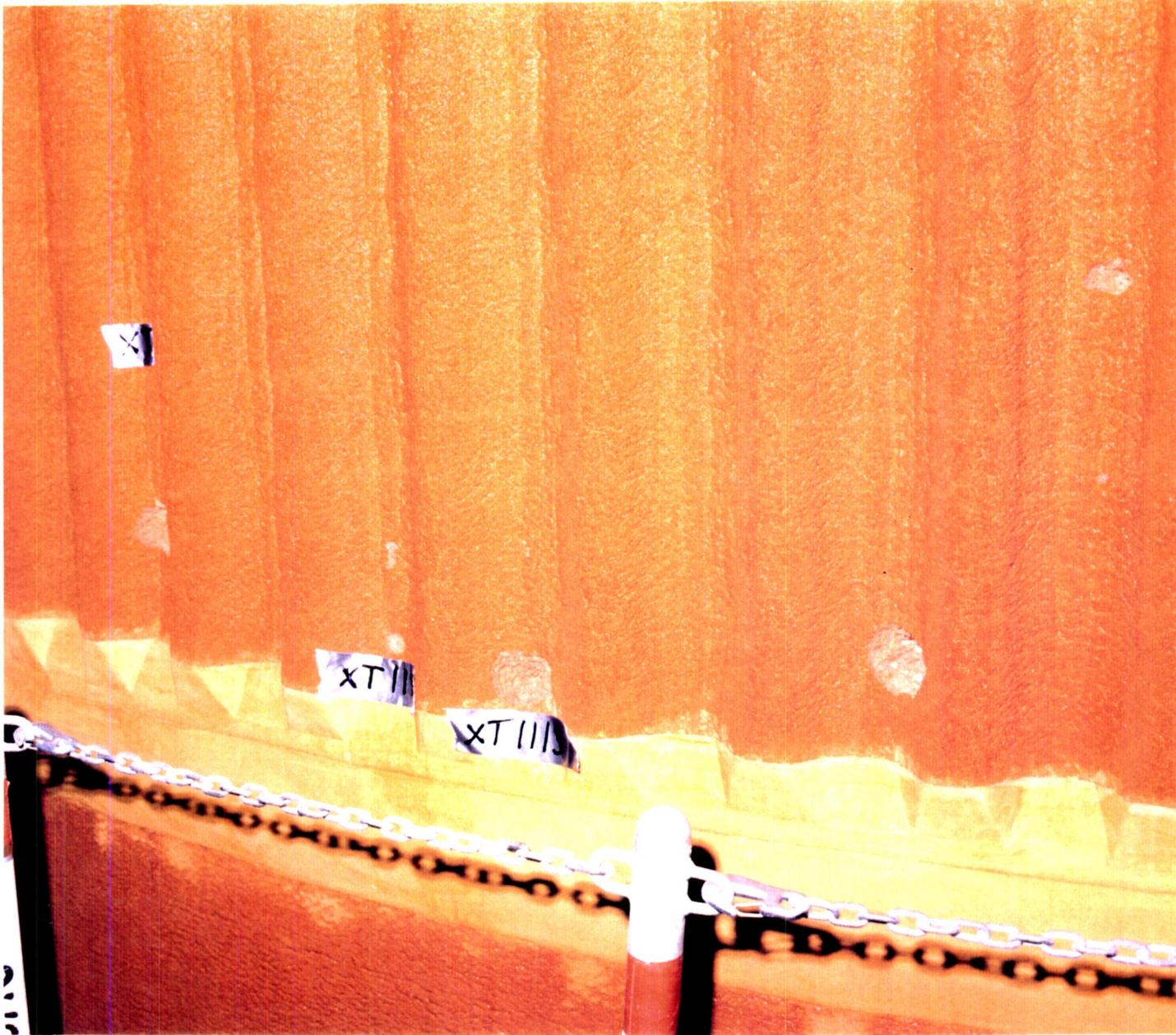


Photo 2 : Woodpecker Damage to Intertank TPS

Cavities, as large as 2 to 3 inches in diameter, had been pecked in the ET TPS by Northern Flicker woodpeckers

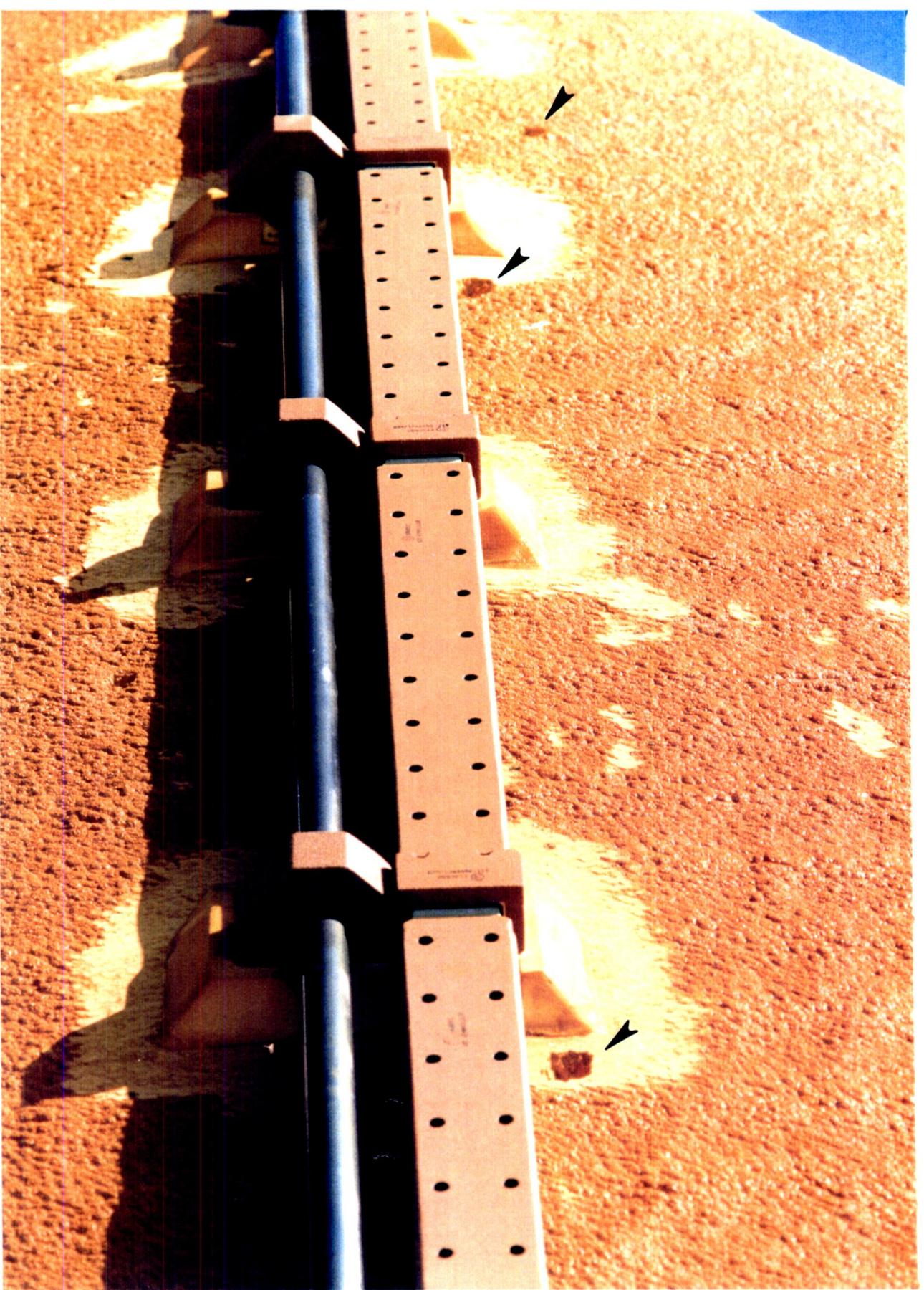


Photo 3 : Woodpecker Damage to LO2 Tank TPS

Woodpecker damage sites on the LO2 tank +Z side were located predominantly along the cable tray/pressurization line. The holes were repaired in the VAB.



Photo 4 : TPS Repairs on the External Tank

More than 170 woodpecker holes were repaired on the External Tank
Note yellow balloon with predator eyes installed on the facility as a woodpecker deterrent

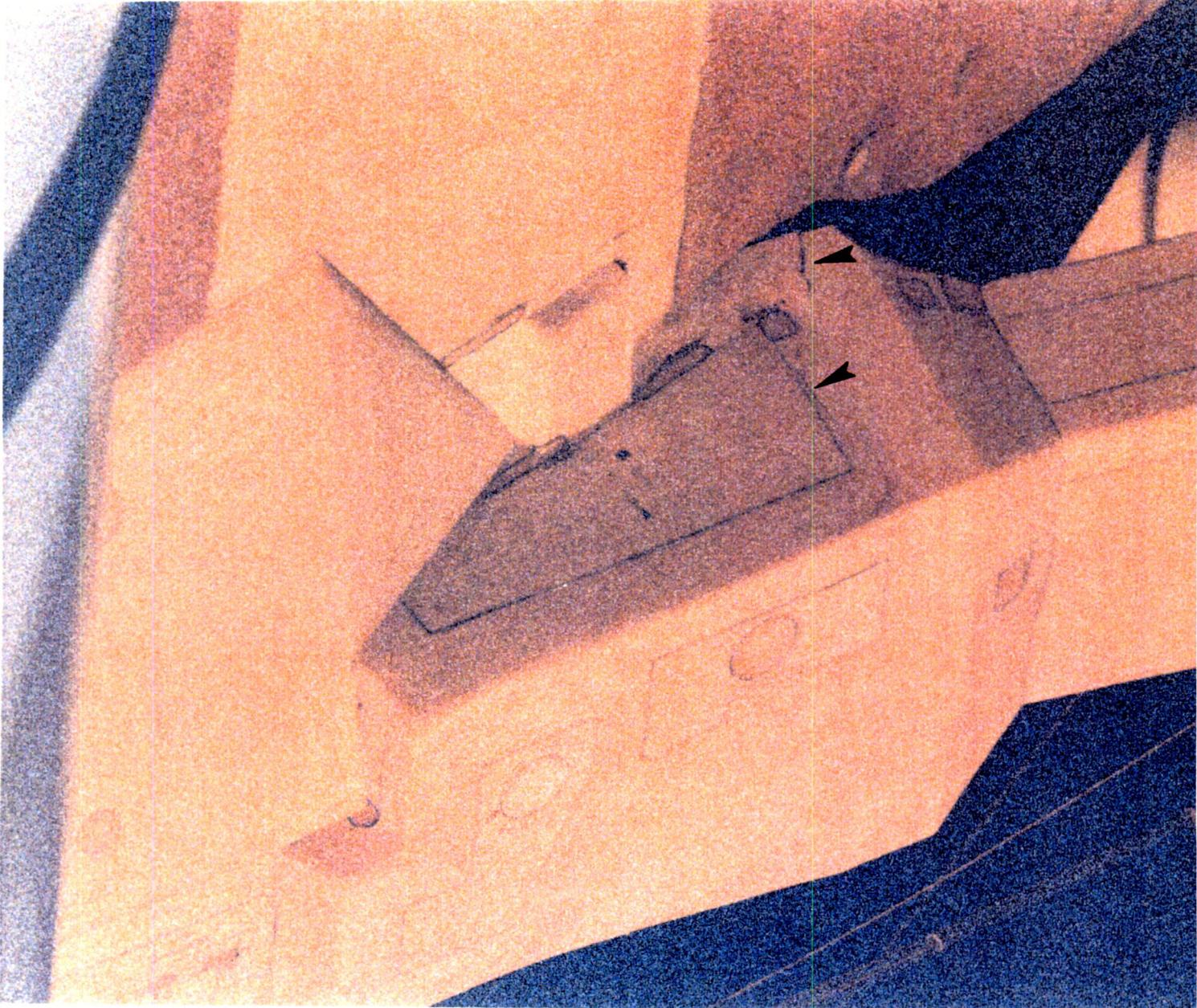


Photo 5 : Two-Crack Condition on -Y ET/SRB Cable Tray

The condition was assessed by the Ice/Debris Team and found acceptable for flight

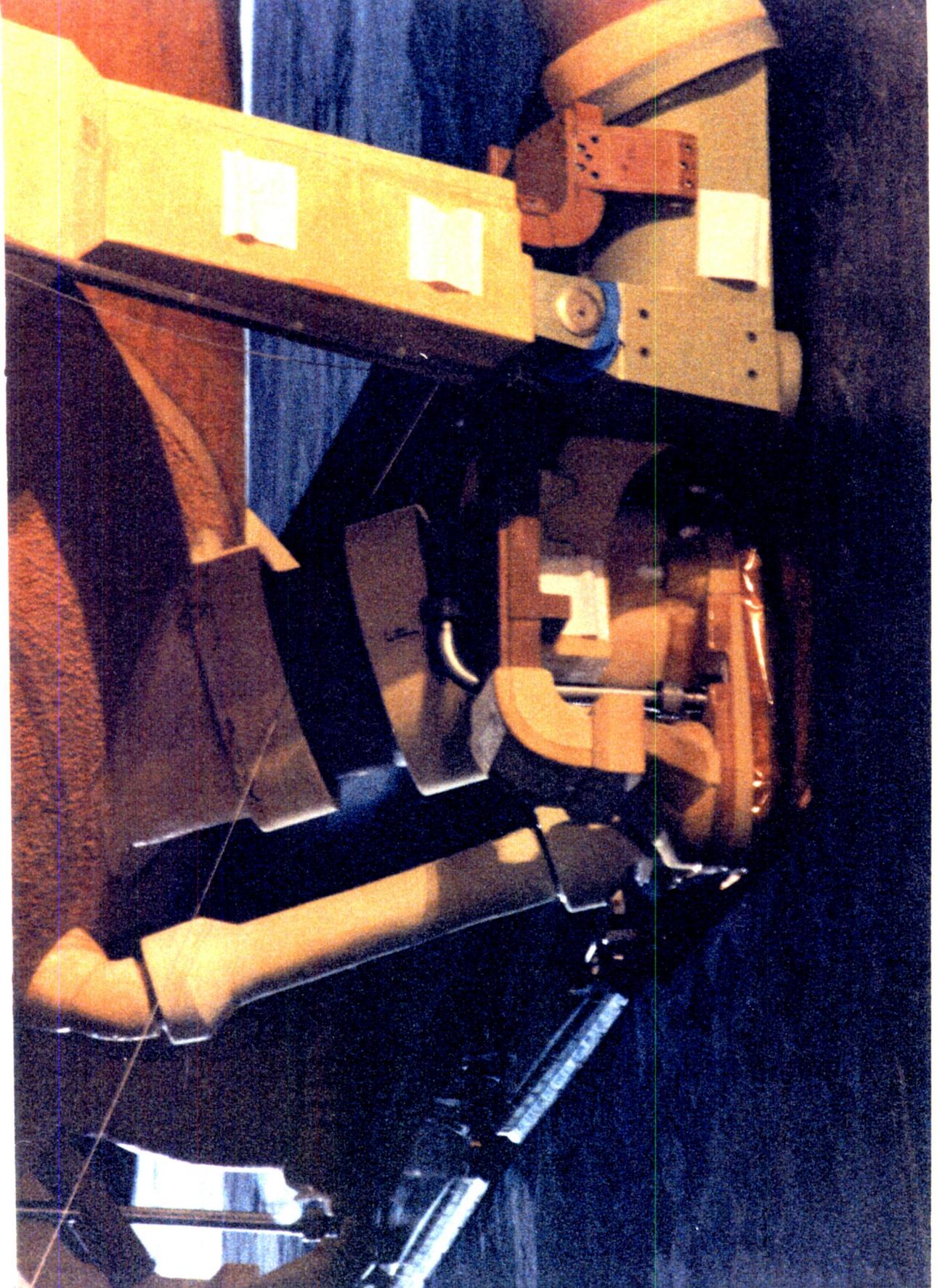


Photo 6 : LH2 ET/ORB Umbilical

Ice/frost accumulations on the umbilical were less than usual



Photo 7 : Woodpecker Hole Repairs After Cryoload

Typical PDL repairs to the woodpecker holes in the External Tank TPS
None of the repairs exhibited ice/frost formations, debonds, or material protrusions

4.0 POST LAUNCH PAD DEBRIS INSPECTION

The post launch inspection of the MLP, FSS, RSS, and pad acreage was conducted immediately after launch on 13 July 1995.

No flight hardware or TPS materials were found.

The loose bolt on the E-16 camera housing/mount checked by the Final Inspection Team at T-3 hours was still attached to the housing after launch.

South SRB HDP erosion was typical. All south HDP shoe EPON shim material was intact. There was no visual indication of a stud hang-up on any of the south holddown posts. All of the north HDP doghouse blast covers were in the closed position. Erosion of the blast covers was minimal.

The Tail Service Masts (TSM), Orbiter Access Arm (OAA), and GOX vent hood appeared undamaged. The GOX seals stuck momentarily to the ET nose cone during vent hood retraction at T-2:30 minutes.

The GH2 vent line had no loose cables (static retract lanyard), and appeared to have latched properly with no rebound. The vent line was latched on the seventh tooth of the latching mechanism. The GUCP seal appeared to be in nominal condition. The vent line blankets near the GUCP had been charred more than usual. A 2-inch by 3/4-inch spring, believed to be from the facility rather than the GUCP, was found laying in the ground umbilical carrier assembly near electrical connector J2.

Extensive damage occurred to the facility cable tray covers running along side the hydrogen cross country fill lines on the northeast side of the pad. Some of the concrete supports were also broken

A total of 14 L-shaped metal brackets, 2-inches by 1-inch by 1/8-inch thick, and a metal plate, 6-inches by 1-inch by 1/8-inch thick, were found on the pad surface.

Typical pad damage included:

- Broken RSS light shade on the 135 foot level

- RSS phone box detached from the wall on the 215 foot level

- Broken locker door on the 235 foot level

- A 4-foot by 2-foot piece of metalized fabric lay in the pad south acreage

Post launch pad inspection anomalies are listed in Section 9.

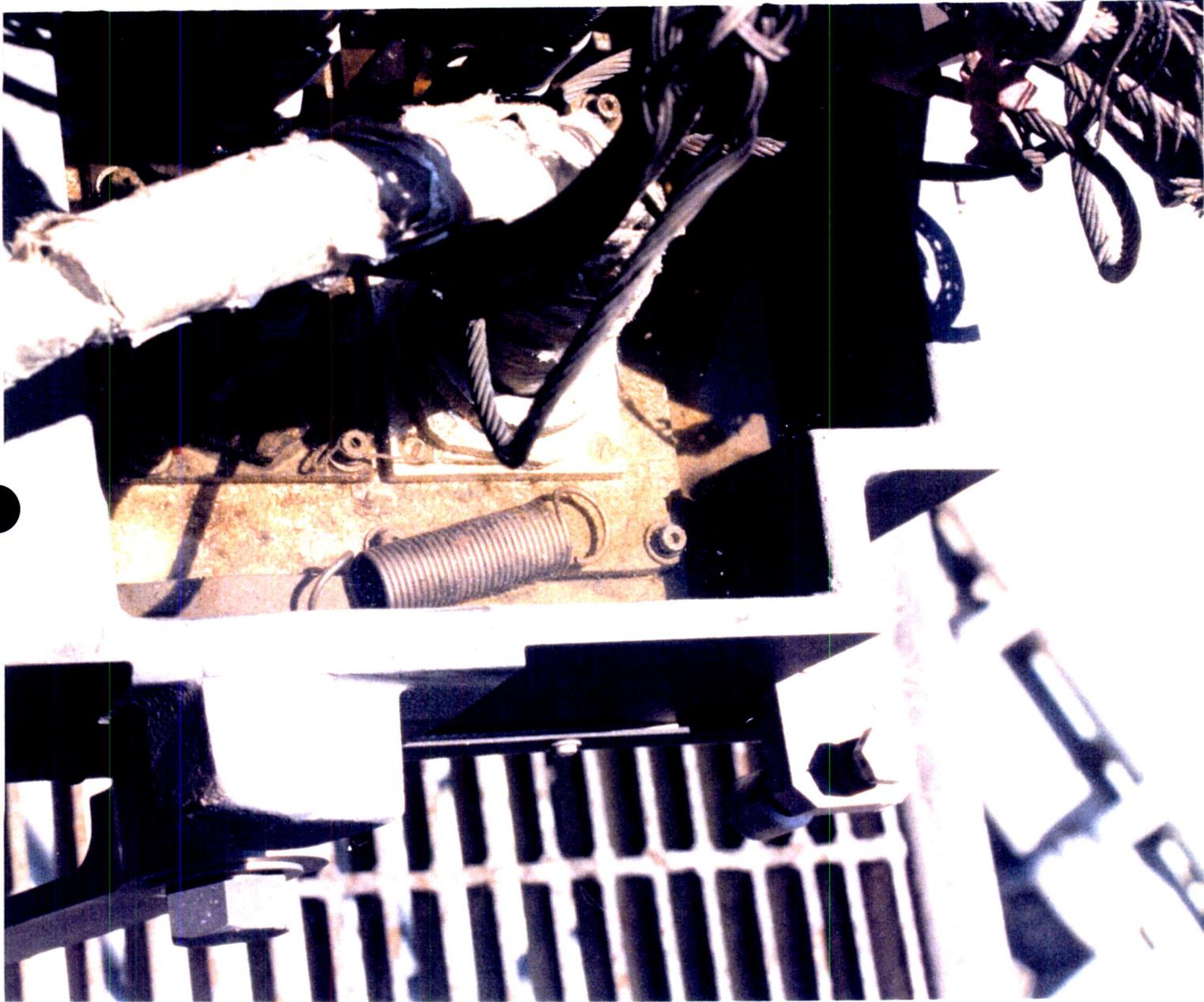


Photo 8 : Loose Spring on GUCP

A 2-inch by 3/4-inch spring, believed to be from the facility rather than the GUCP, was found laying in the ground umbilical carrier assembly near electrical connector J2



Photo 9 : Launch Pad Damage

Extensive damage occurred to the facility cable tray covers running along side the hydrogen cross country fill lines on the northeast side of the pad. Some of the concrete supports were also broken

5.0 FILM REVIEW

Anomalies observed in the Film Review were presented to the Mission Management Team, Shuttle managers, and vehicle systems engineers. No IPR's or IFA's were generated as a result of the film review. Post flight anomalies are listed in Section 9.

5.1 LAUNCH FILM AND VIDEO SUMMARY

A total of 102 films and videos, which included thirty-nine 16mm films, twenty-one 35mm films, four 70mm films, and thirty-eight videos, were reviewed starting on launch day.

No vehicle damage or lost flight hardware was observed that would have affected the mission.

Both northeast and southwest GOX vent seals stuck momentarily to the External Tank nosecone topcoat during seal deflation/retraction at T-2:30. No significant amounts of missing topcoat were noted. Residual GOX vapors vented from the frost-coated ET northeast louver. The External Tank "twanged" approximately 32 inches during SSME ignition (E-79).

SSME ignition and gimbal appeared normal (OTV 151, 170, 171). A flare occurred in the SSME #3 plume during startup (E-2). One flare occurred in the SSME #1 exhaust plume prior to liftoff. A dark object, most likely a moth, fell from a dark area on the LH OMS pod at 13:41:50.317 GMT (E-77).

SSME ignition caused ice to shake loose from the forward side of the LH2 ET/ORB umbilical, fall onto the cable tray, deflect toward the Orbiter, contact tiles in the vicinity of the umbilical cavity sill, and rebound away from the Orbiter at 13:42:52.047 GMT. No tile damage was visible (OTV 109, OTV 163).

One piece of ice from the LH2 ET/ORB umbilical contacted the feedline support bracket and Orbiter tiles near the disconnect area. No TPS damage was visible.

Dirt or tile "dust" emanated from left inboard and outboard elevon lower surface tiles near the elevon hinge line during SSME ignition at 13:41:50.077 GMT (OTV 109, OTV 064; E-31).

Small pieces of tile surface coating material were lost from two places on the base heat shield including one place outboard of SSME #3 (OTV 149; E-17, -18, -19, -20).

GUCP disconnect from the ET was nominal (E-33). GH2 vent line retraction and latch were normal. Pieces of ice shook loose from the GUCP and fell aft without contacting flight hardware (E-41, -50, -60).

Ice was shaken loose from the LO2 feedline upper bellows, but no impacts to flight hardware were observed (E-65).

A large piece of aft skirt instafoam, approximately 18 inches long by 10 inches wide by 10 inches thick, stuck to the RH SRB aft skirt purge line as the vehicle lifted off holddown post #2. Loss of this foam piece was not a safety-of-flight concern (E-8). The SRB plume most likely fragmented this foam into numerous smaller pieces in the north flame trench. (The area of missing foam under the aft skirt was visible in film item E-25).

No stud hang-ups occurred on any of the holddown posts. No ordnance fragments or frangible nut pieces fell from any of the DCS/stud holes (E-7 through E-14). Pieces of aluminum tape came loose from HDP firing lines and fell into the SRB exhaust hole (E-13, -14).

A debris particle moved eastward under the Orbiter right wing at liftoff, but no contact with the flight hardware was observed (E-1).

Although an expected event, more than usual amounts of SRB throat plug and sound suppression water trough material exited the SRB exhaust holes at T-0 (E-1, -4, -15, -16).

Two dark-colored objects first appeared above the LO2 TSM but actually originated from an area behind the RH SRB at 13:41:56.661 GMT. The objects may have been ejected upward out of the SRB exhaust hole, but did not contact flight hardware in this field of view (E-76).

Two pieces of red SRB sound suppression water trough passed the LO2 TSM shortly after liftoff. A large chunk of SRB throat plug material was ejected upward out of the SSME flame trench south of the MLP, but the piece did not contact flight hardware (E-77).

A debris particle fell from the GOX vent arm area after the vehicle had cleared the tower (E-62).

Several larger-than-usual pieces of LH2 and LO2 ET/ORB umbilical purge barrier baggie material fell aft past the body flap into the SRB plume at 13:42:11.800 GMT (E-52).

Body flap movement (amplitude and frequency) was similar to previous flights (E-212, -220).

Tape had come loose on SRB aft skirt thermal curtains during ascent (E-207).

Localized flow condensation collars formed on the vehicle during ascent starting at 13:42:38 GMT. This is an expected occurrence given the ambient weather conditions at the time of launch (TV-2, TV-4, TV-13; film items E-220, -222, -224).

A blurred white object passing across the External Tank at 13:42:53.521 GMT is believed to be an insect close to the camera lens (TV-4). A second blurred object crossing the field of view from right to left and making an abrupt turn near the exhaust plume at 13:44:02 GMT is also believed to be a bird or insect near the camera lens (TV-21).

Exhaust plume recirculation, ET aft dome charring, and SRB separation appeared normal (E-208, -220).

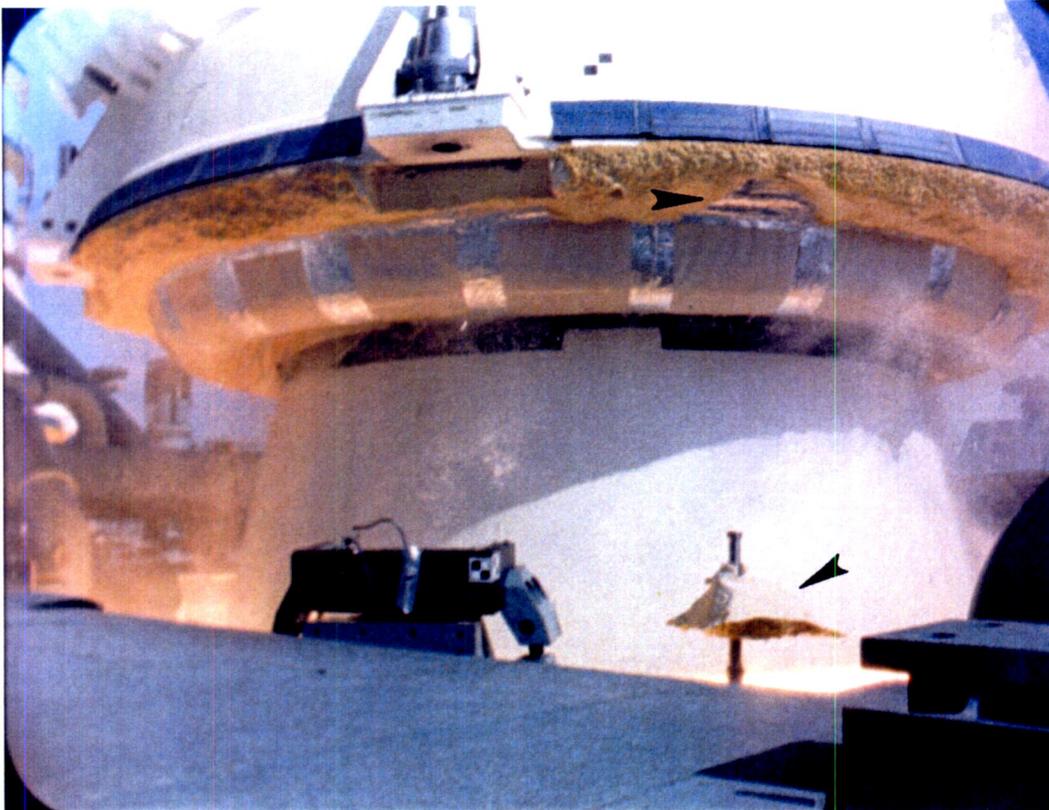


Photo 10 : Aft Skirt Instafoam Pulled Loose

A large piece of aft skirt instafoam, approximately 18 inches long by 10 inches wide by 10 inches thick, stuck to the RH SRB aft skirt purge line as the vehicle lifted off holddown post #2. Loss of this foam piece was not a safety-of-flight concern.

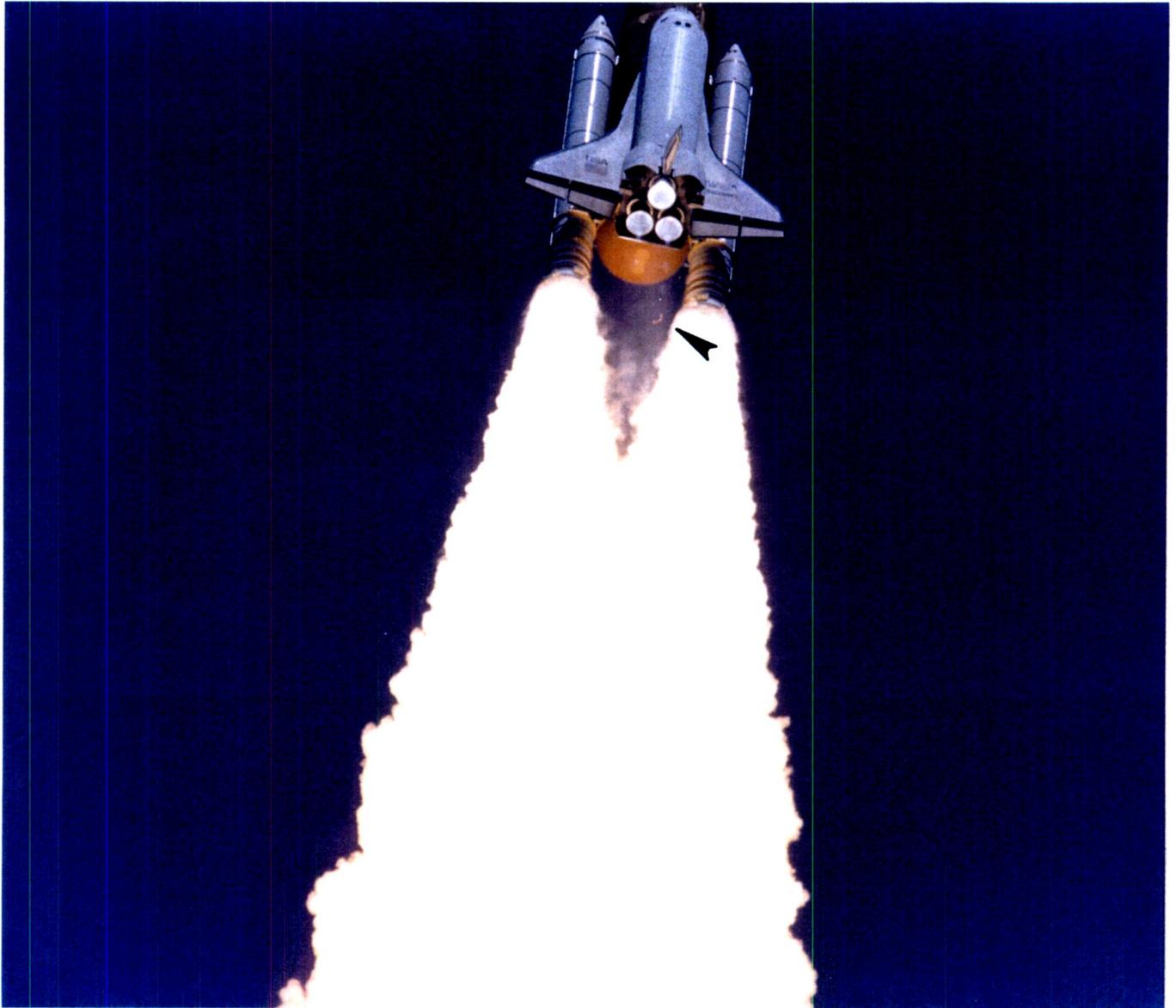


Photo 11 : Umbilical Purge Barrier Material

Several larger-than-usual pieces of LH2 and LO2 ET/ORB umbilical purge barrier baggie material fell aft past the body flap into the SRB plume at 13:42:11.800 GMT

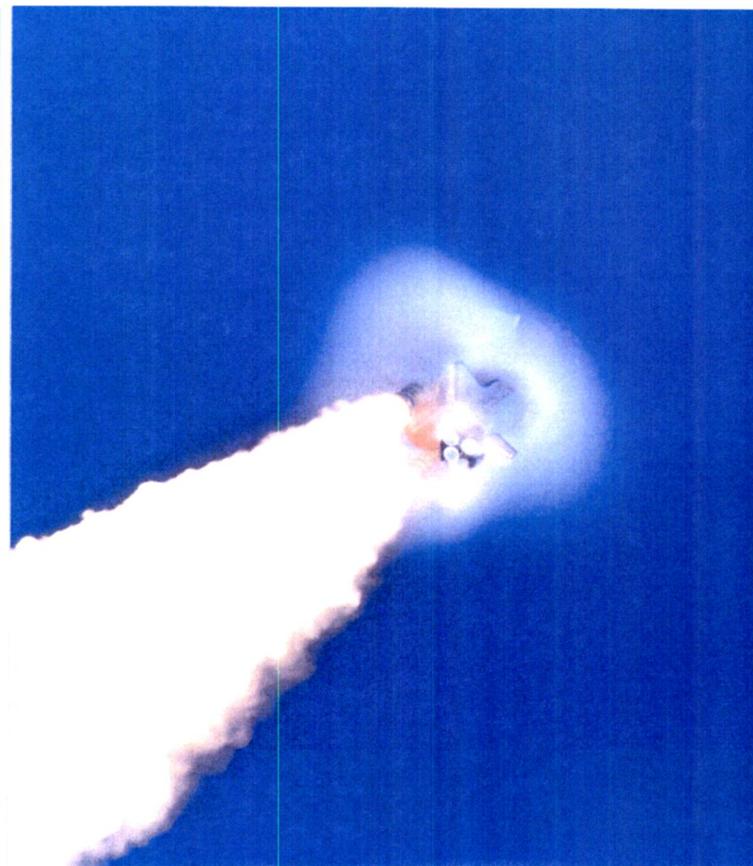
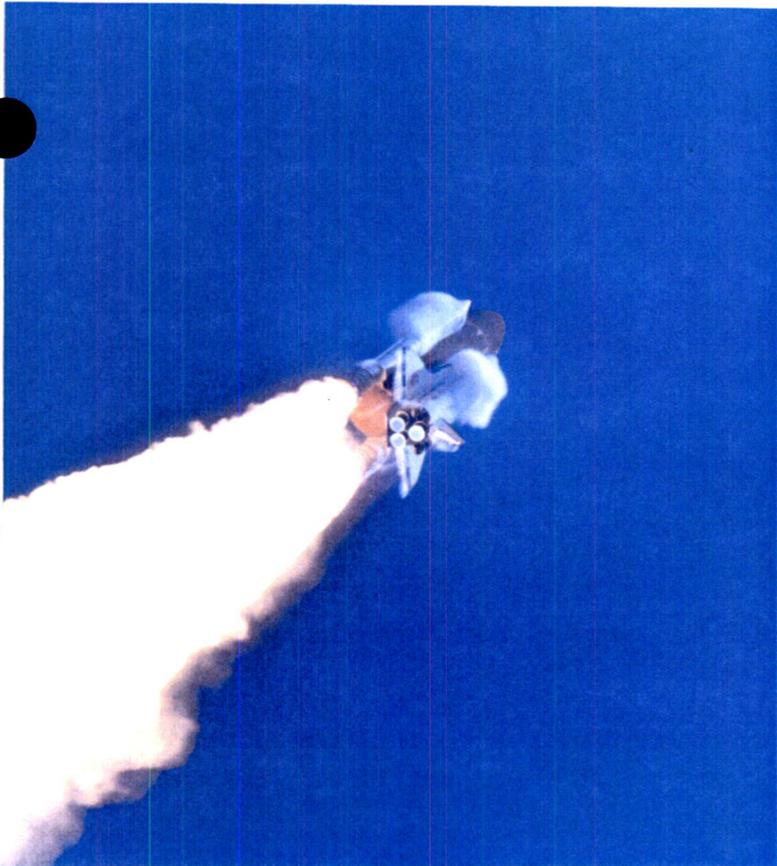


Photo 12 : Condensation Collars and Moisture Layers

Localized flow condensation collars formed on the vehicle due to supersonic shock waves and passage through atmospheric moisture layers during ascent starting at 13:42:38 GMT. This was an expected occurrence given the warm, humid ambient weather conditions at the time of launch.

5.2 ON-ORBIT FILM AND VIDEO SUMMARY

DTO-0312 was performed by the flight crew. Thirty-seven hand-held still images were obtained of ET-71 after separation from the Orbiter. Coverage of the ET +Z side was especially good. OV-103 was not equipped to carry umbilical cameras.

No vehicle damage or lost flight hardware was observed that would have been a safety of flight concern.

ET structural separation from the Orbiter appeared nominal. The LH2 and LO2 tank acreage was in good condition with no visible divots. The BSM burn scars on the LO2 tank were typical. No anomalies were observed on the nosecone, PAL ramps, RSS antennae, flight door, GUCP area, LO2 feed line, and aft hard point. Exhaust plume recirculation effects on the manhole cover closeouts and aft dome apex was also typical. Charring and erosion of aft dome TPS was similar to that observed on previous missions.

Unusual comprehensive photographic coverage of the ET +Z side showed no intertank acreage or stringer head divots and no intertank-to-LH2 tank flange closeout divots. Light-colored areas on the -Z side of the intertank were previous repairs and sanded areas, rather than new divots, documented prior to flight.

Both redesigned bipod jack pad closeouts were intact and appeared to be in good condition.

No divots or TPS anomalies were observed at the locations of the woodpecker damage site repairs.

Note: The total number of Orbiter lower surface tile damage sites was below average for this flight. The number of damage sites with a major dimension of 1-inch or larger was significantly below average and one of the lowest counts to date when compared to previous flights.

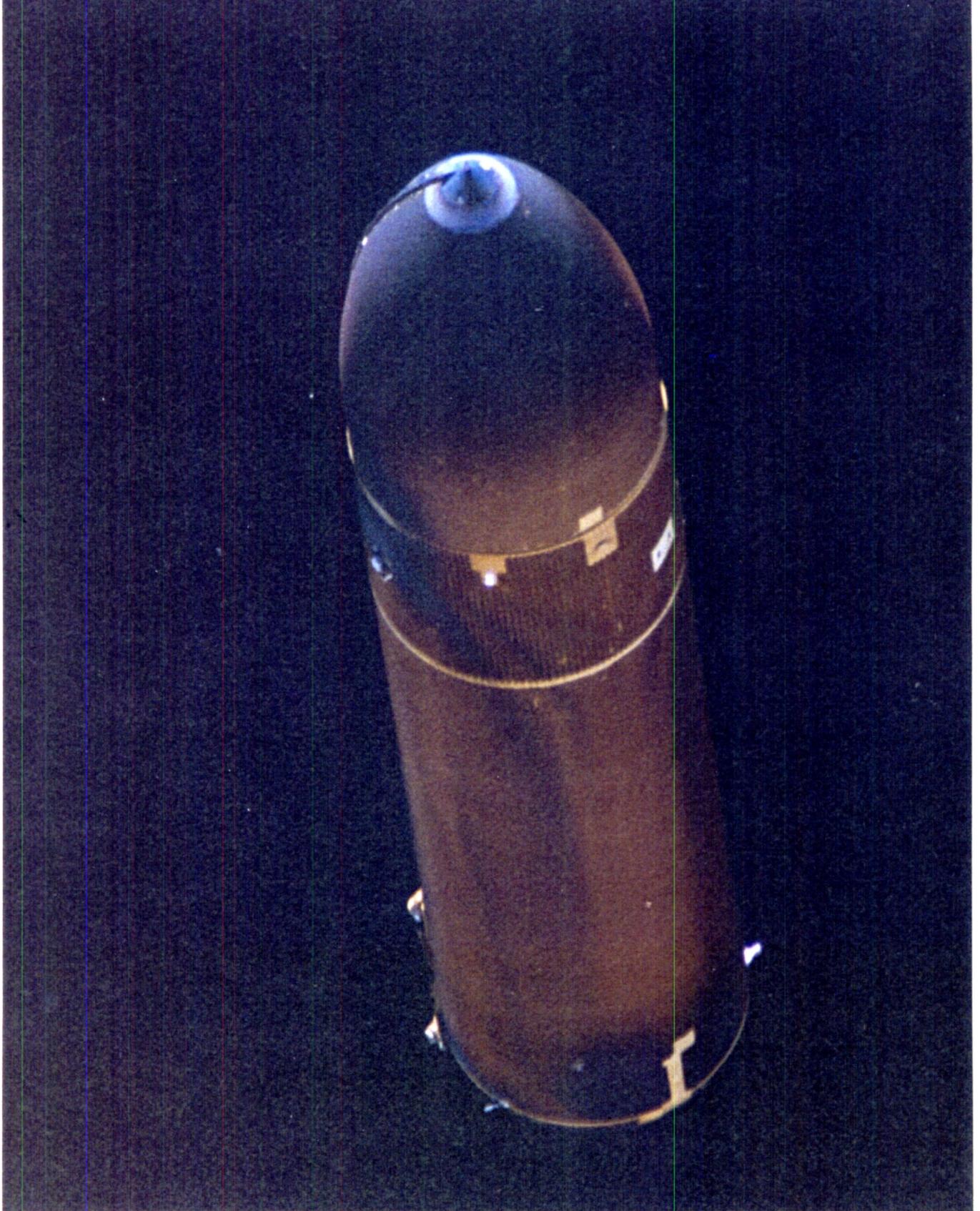


Photo 13 : ET After Separation from Orbiter

No divots or TPS anomalies were observed at the locations of the woodpecker damage site repairs. Light-colored areas on the -Z side of the intertank were previous repairs and sanded areas, rather than new divots, documented prior to flight.

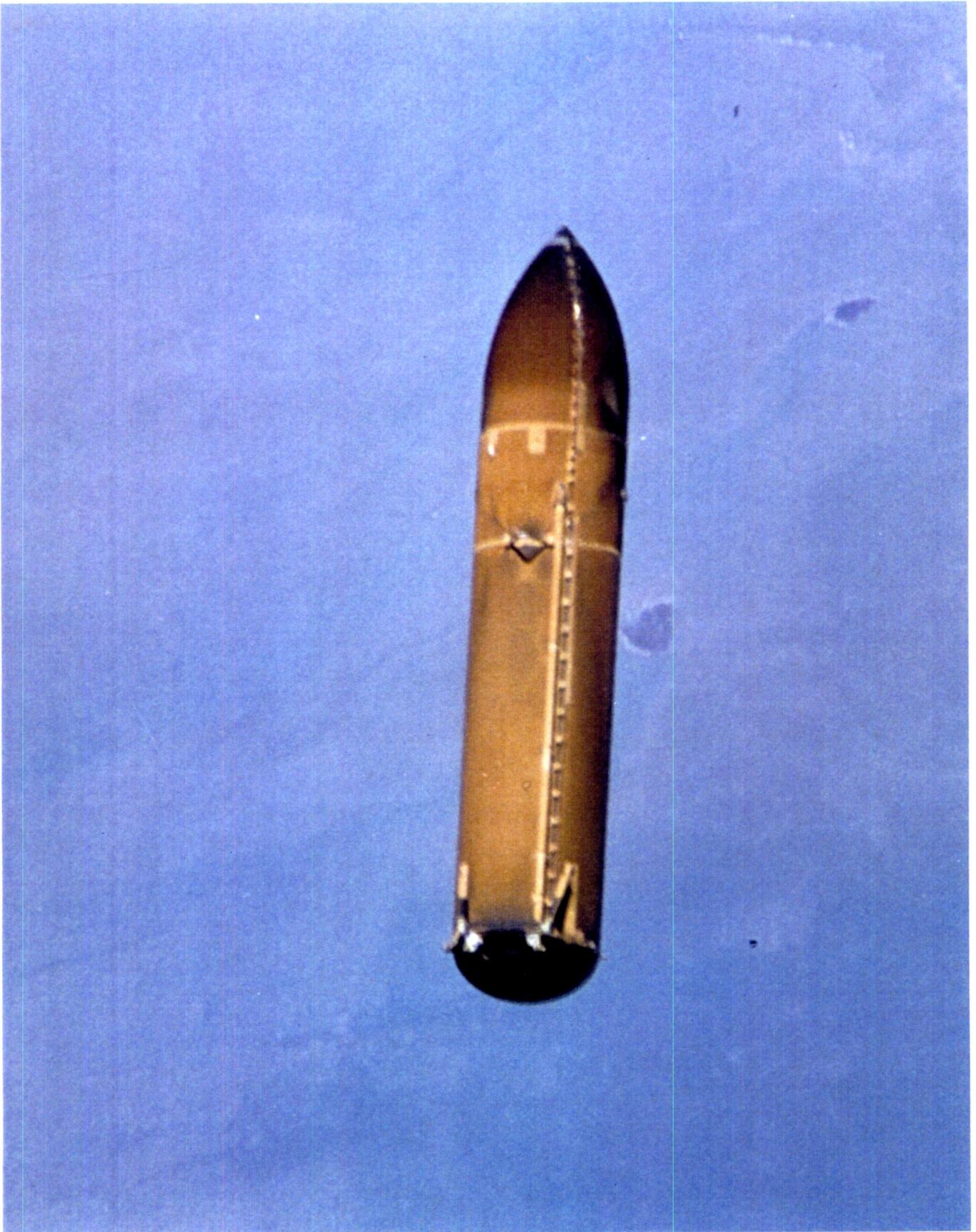


Photo 14 : External Tank +Z Side

Unusual comprehensive photographic coverage of the ET +Z side showed no intertank acreage or stringer head divots and no intertank-to-LH2 tank flange closeout divots. Both redesigned bipod jack pad closeouts were intact and appeared to be in good condition.

5.3 LANDING FILM AND VIDEO SUMMARY

A total of 22 film and video items, including one 16mm film, nine 35mm large format films, and twelve videos, were reviewed.

Orbiter performance on final approach appeared normal. There were no anomalies when the landing gear was extended. Contrails streamed aft of the wing tips. Both main gear touched down almost simultaneously. There were no unusual control surface deflections. Touchdown of the nose landing gear was smooth. Although four rubber pieces from the nose gear tires were recovered on the runway, the event causing the loss of material was not visible in the films.

Drag chute deployment appeared nominal. The Orbiter drifted slightly east of runway centerline during rollout before correcting back to centerline.

Rollout and wheel stop were uneventful. No large tile damage sites were visible on the Orbiter lower surface. Infrared views of landing showed no unusual thermal events.

A large format 35mm camera was positioned in line with the runway threshold line to determine the altitude of the Orbiter crossing the runway threshold using photographic means. That value would then be compared at JSC to the Orbiter on-board instrumentation. Measurements on the film were taken when the left main landing gear tire was centered over the 10 foot wide threshold line at GMT 12:01:52.209. An altitude of 21.8 feet from the lowest point on the left main gear tire to the runway surface (left wing was slightly lower than right wing when crossing the threshold) was calculated. Or, the lowest point on the right main gear tire was 22.9 feet above the runway surface.

6.0 SRB POST FLIGHT/RETRIEVAL DEBRIS ASSESSMENT

The BI-073 Solid Rocket Boosters were inspected for debris damage and debris sources at CCAFS Hangar AF on 17 July 1995. From a debris standpoint, both SRB's were in good condition.

6.1 RH SOLID ROCKET BOOSTER DEBRIS INSPECTION

The RH frustum was missing no TPS. The number of debonds (29) over fasteners was average (Figure 1). Hypalon paint was blistered/missing where BTA closeouts had been applied. Some of the underlying BTA was sooted. The BSM aero heat shield covers had locked in the fully opened position though the left two cover attach rings had been bent by parachute riser entanglement.

The RH forward skirt exhibited no debonds or missing TPS. Both RSS antennae covers/phenolic base plates were intact. Hypalon paint was blistered/missing over the areas where BTA closeouts had been applied. No pins were missing from the frustum severance ring.

Separation of the aft ET/SRB struts appeared normal. No K5NA was missing from the separation plane of the upper strut fairing. The ETA ring, IEA, and IEA covers appeared undamaged by debris. All three stiffener rings were damaged from water impact. The aft booster stiffener ring splice plate closeouts were intact and no K5NA material was missing.

Aft skirt hypalon paint was blistered over areas where BTA closeouts had been applied. A 0.4 inch long by 0.1 inch wide by 0.15 inch deep gouge on the forward-facing surface of the aft outboard BSM fairing (closest to the +Z axis) was analyzed by the MSFC materials laboratory, which determined the gouge was most likely caused by SRM insulation NBR rubber (reference PR PV6290235 and USBI Report BLV-050-95MP). The BSM aft attach bracket adjacent to HDP #1 was missing K5NA to substrate. The HDP Debris Containment System (DCS) plungers were seated and appeared to have functioned properly.

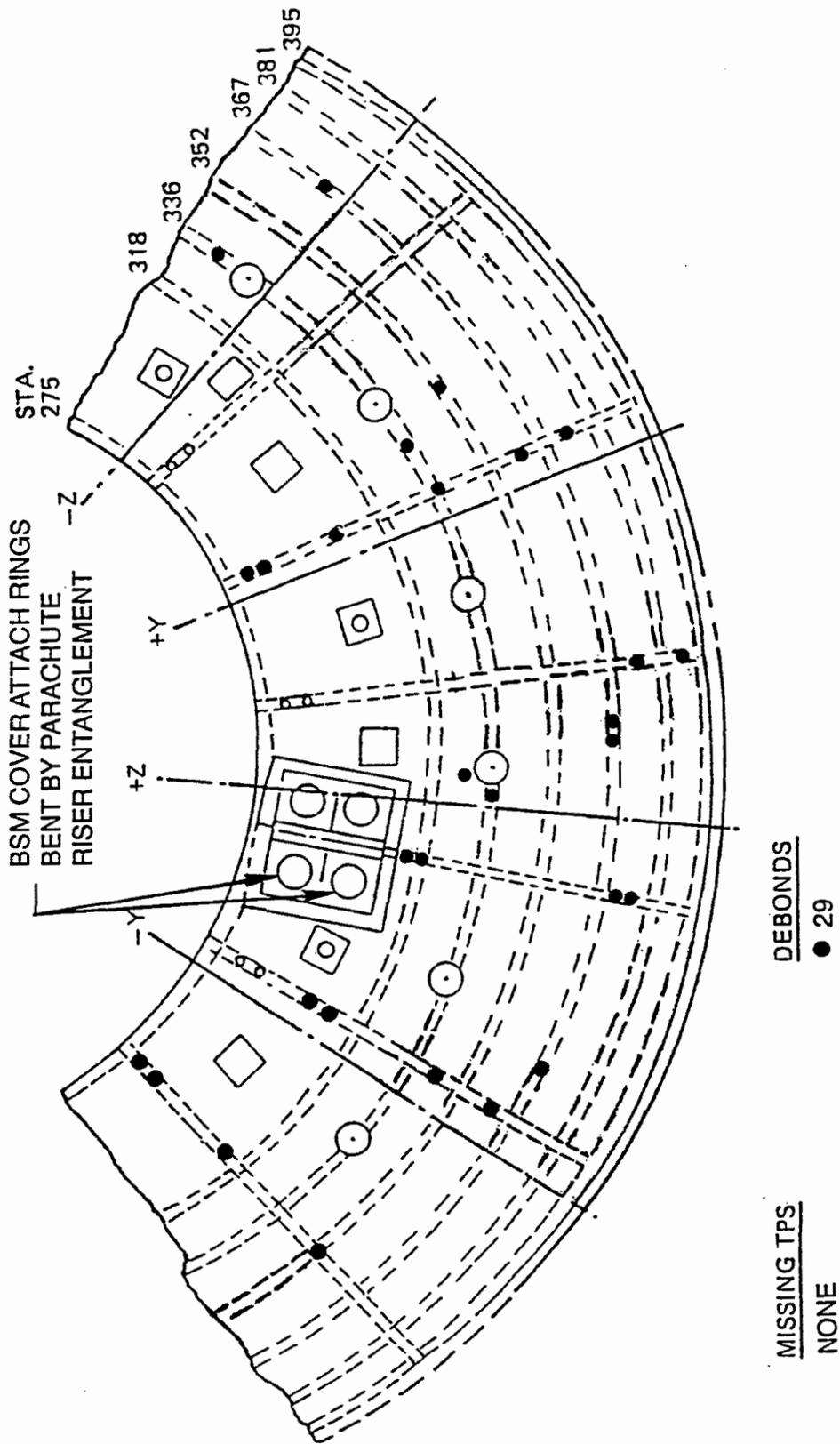


Figure 1 : RH SRB Frustum

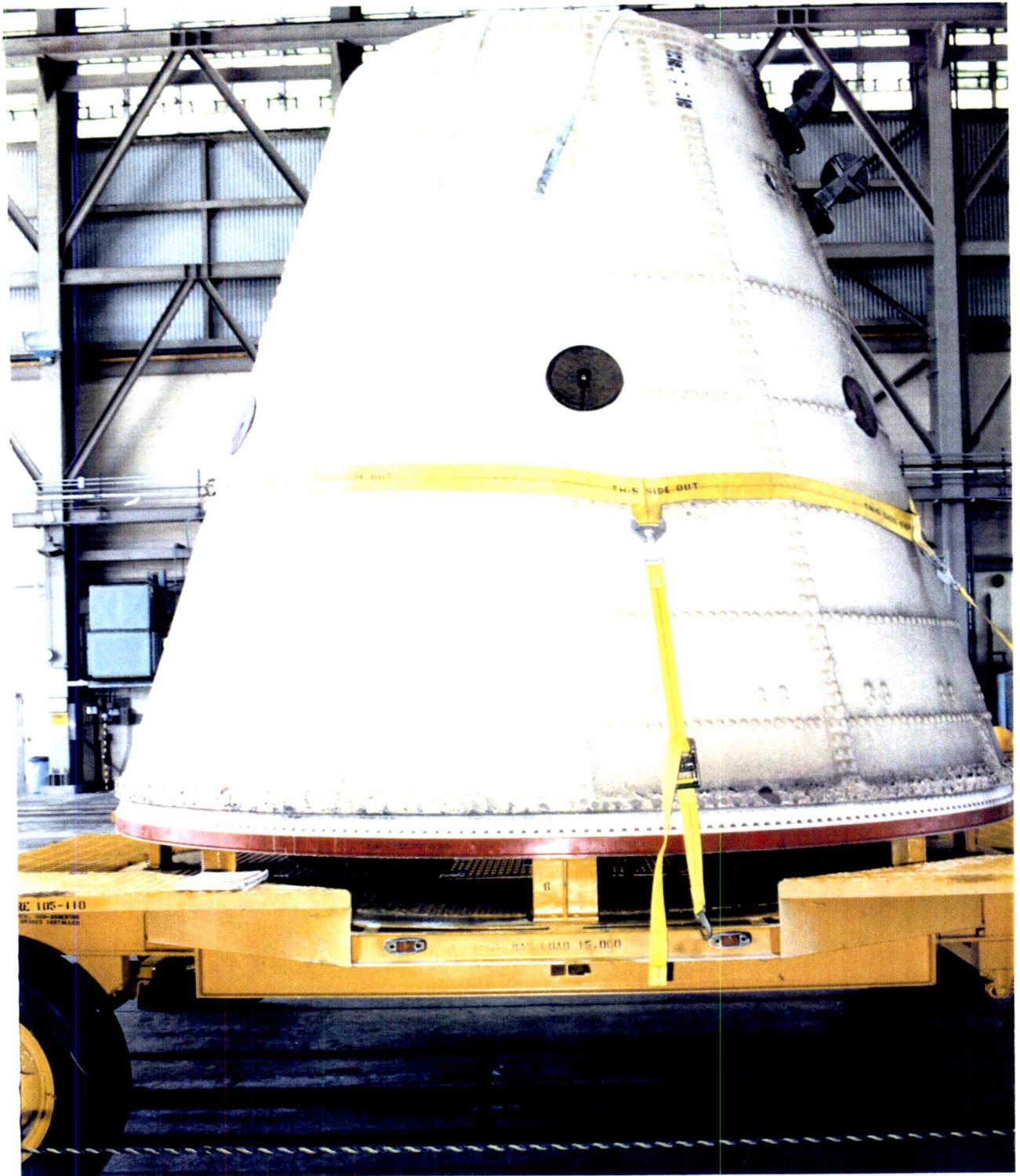


Photo 15 : RH SRB Frustum

The RH frustum was missing no TPS. The number of debonds (29) over fasteners was average. Hypalon paint was blistered/missing where BTA closeouts had been applied. The BSM aero heat shield covers had locked in the fully opened position though the left two cover attach rings had been bent by parachute riser entanglement.

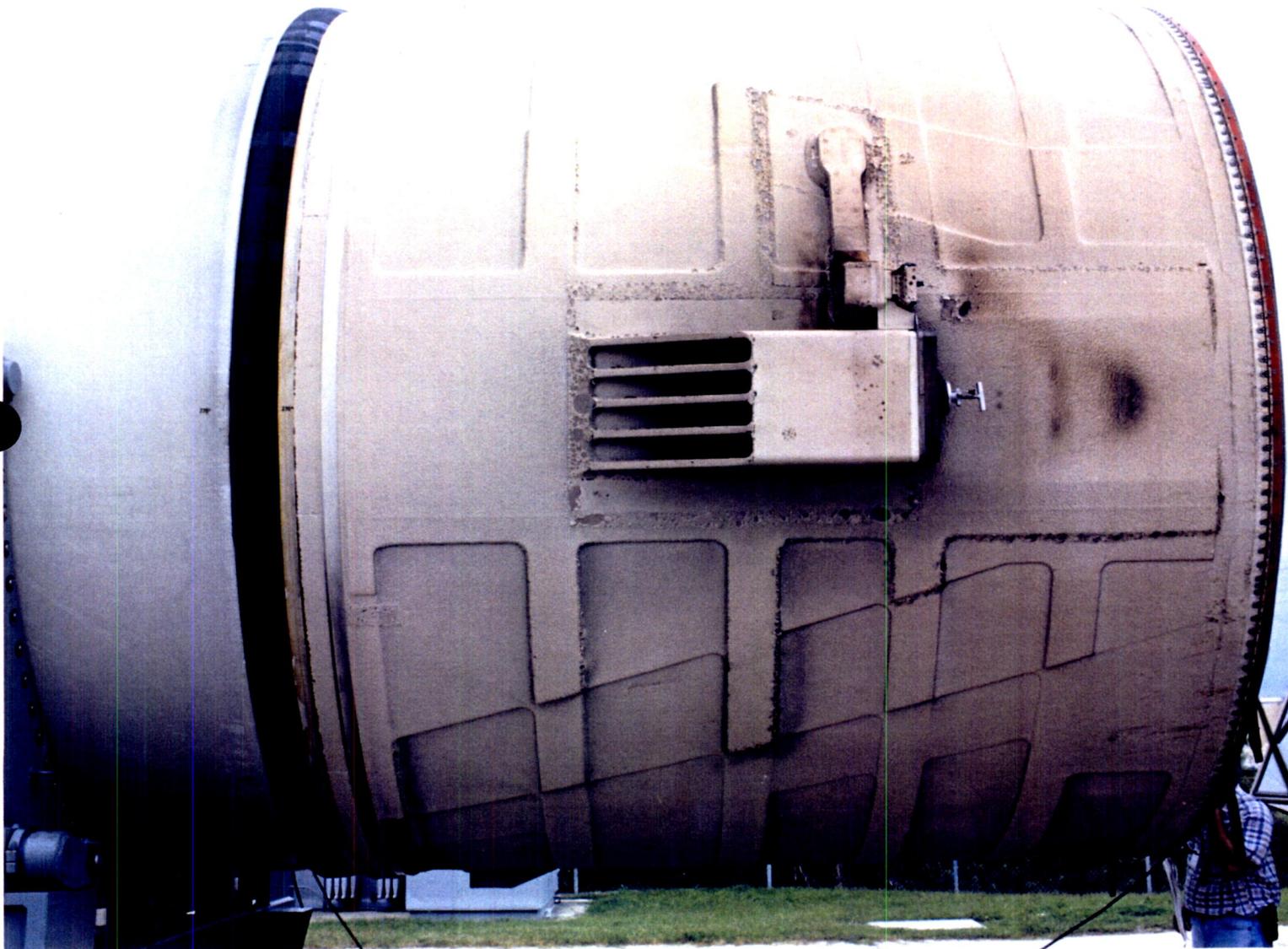


Photo 16 : RH Forward Skirt

The RH forward skirt exhibited no debonds or missing TPS. Hypalon paint was blistered/missing over the areas where the BTA closcouts had been applied.

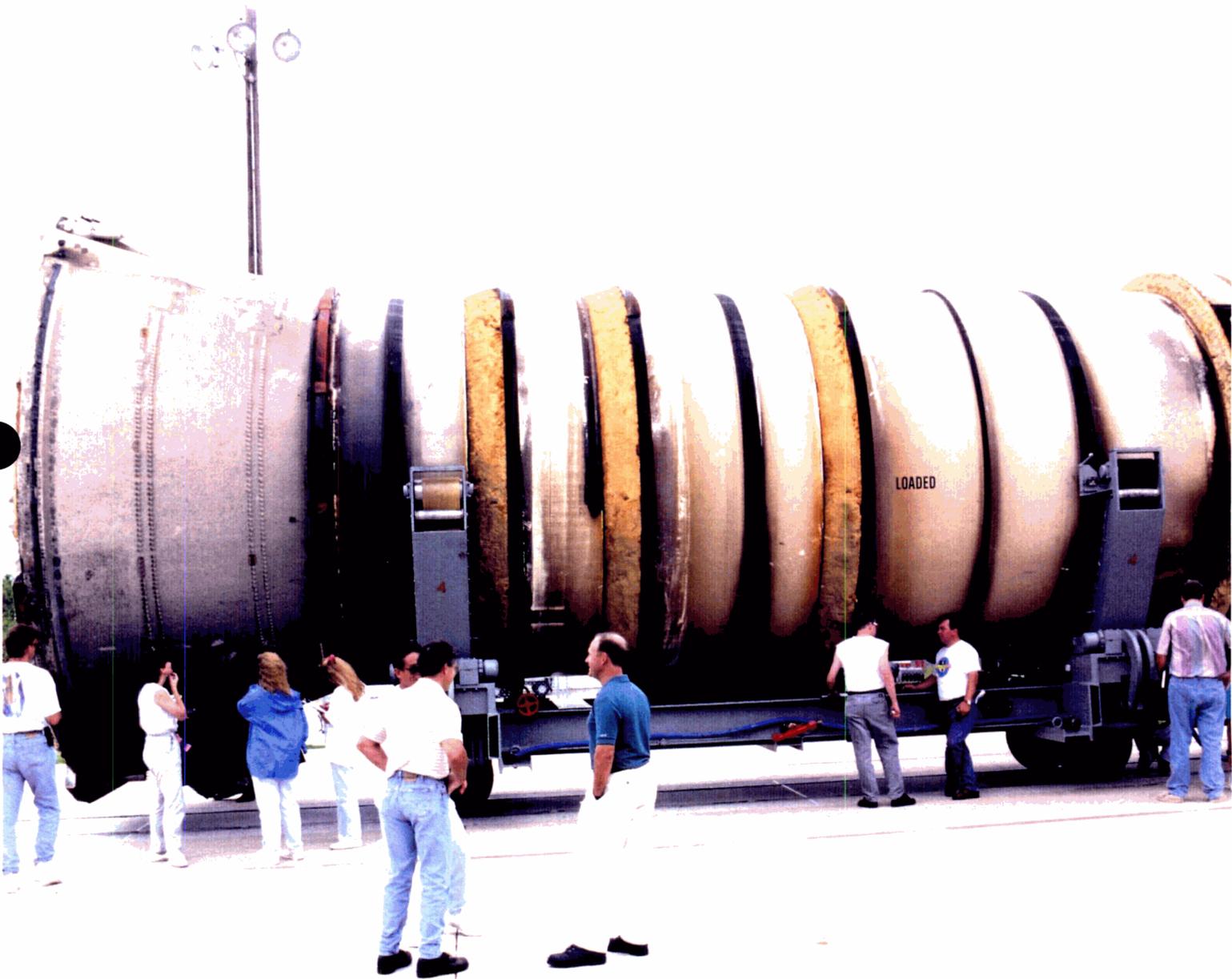


Photo 17 : RH Aft Booster/Aft Skirt



Photo 18 : Gouge on RH Aft BSM Fairing

A 0.4 inch long by 0.1 inch wide by 0.15 inch deep gouge on the forward-facing surface of the aft outboard BSM fairing (closest to the +Z axis) was most likely caused by SRM insulation NBR rubber

6.2 LH SOLID ROCKET BOOSTER DEBRIS INSPECTION

The LH frustum was missing no TPS. The number of MSA-2 debonds (28) over fasteners was average (Figure 2). Hypalon paint was blistered/missing along the XB-395 ring frame where BTA closeouts had been applied. Some of the underlying BTA was sooted. The BSM aero heat shield covers had locked in the fully opened position.

The LH forward skirt exhibited no debonds or missing TPS. Both RSS antennae covers/phenolic base plates were intact. Hypalon paint was blistered/missing over the areas where BTA closeouts had been applied. No pins were missing from the frustum severance ring.

Separation of the aft ET/SRB struts appeared normal. No K5NA was missing from the separation plane of the upper strut fairing. However, the fairing was deformed as a result of water impact. The ETA ring, IEA, and IEA covers appeared undamaged. All three of the stiffener rings were cracked from water impact. The stiffener ring splice plate closeouts were intact and no K5NA material was missing.

Two 5"x2" MSA-2 divots were present over aft skirt fastener heads. The divots appeared to expose lightly-sooted substrate. Hypalon paint was blistered/missing over the areas where BTA closeouts had been applied. The HDP Debris Containment System (DCS) plungers were seated and appeared to have functioned properly with the exception of HDP #7. The plunger had been obstructed by a frangible nut half most likely as the result of water impact.

SRB Post Launch Anomalies are listed in Section 9.

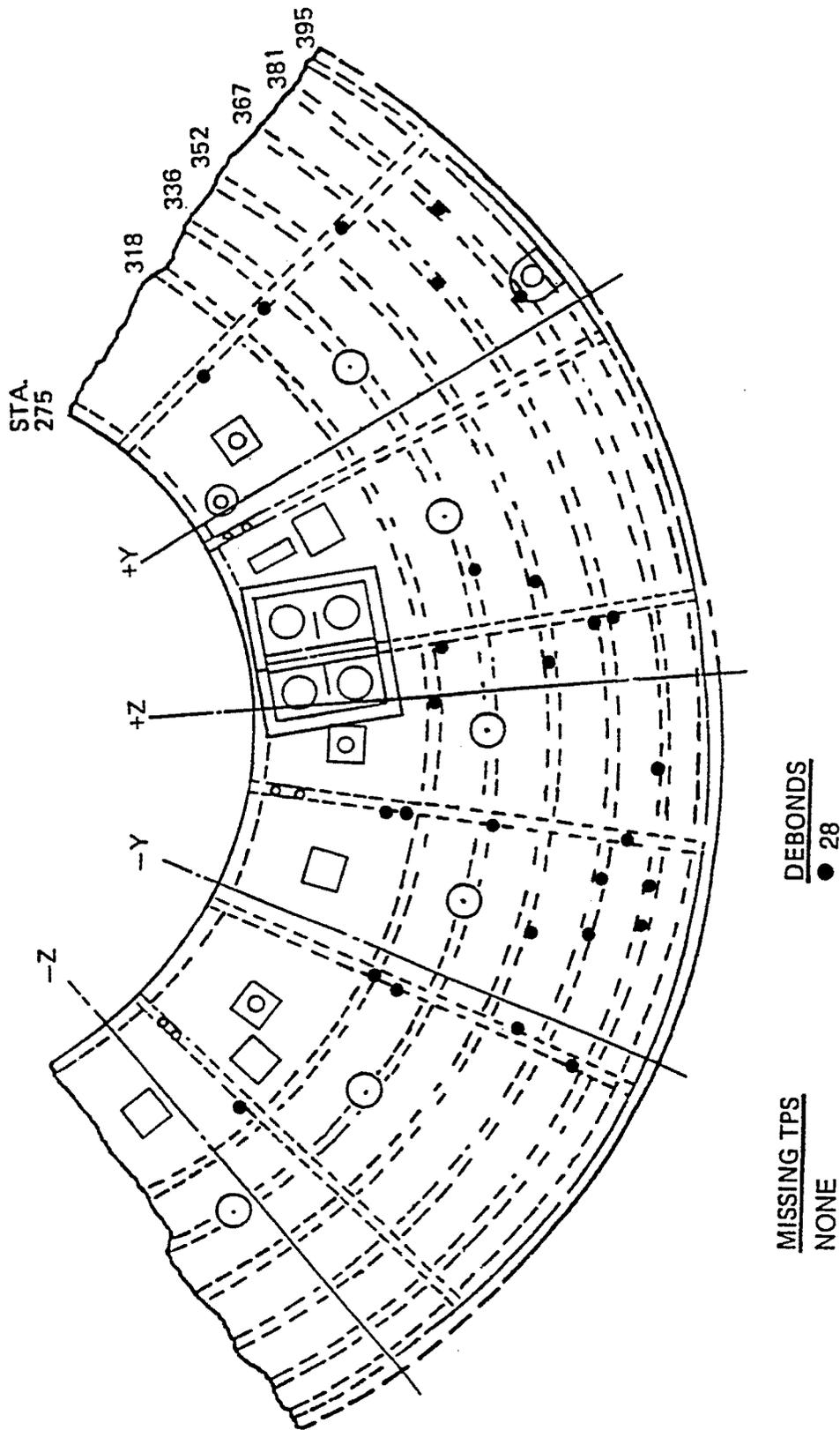


Figure 2 : LH SRB Frustum

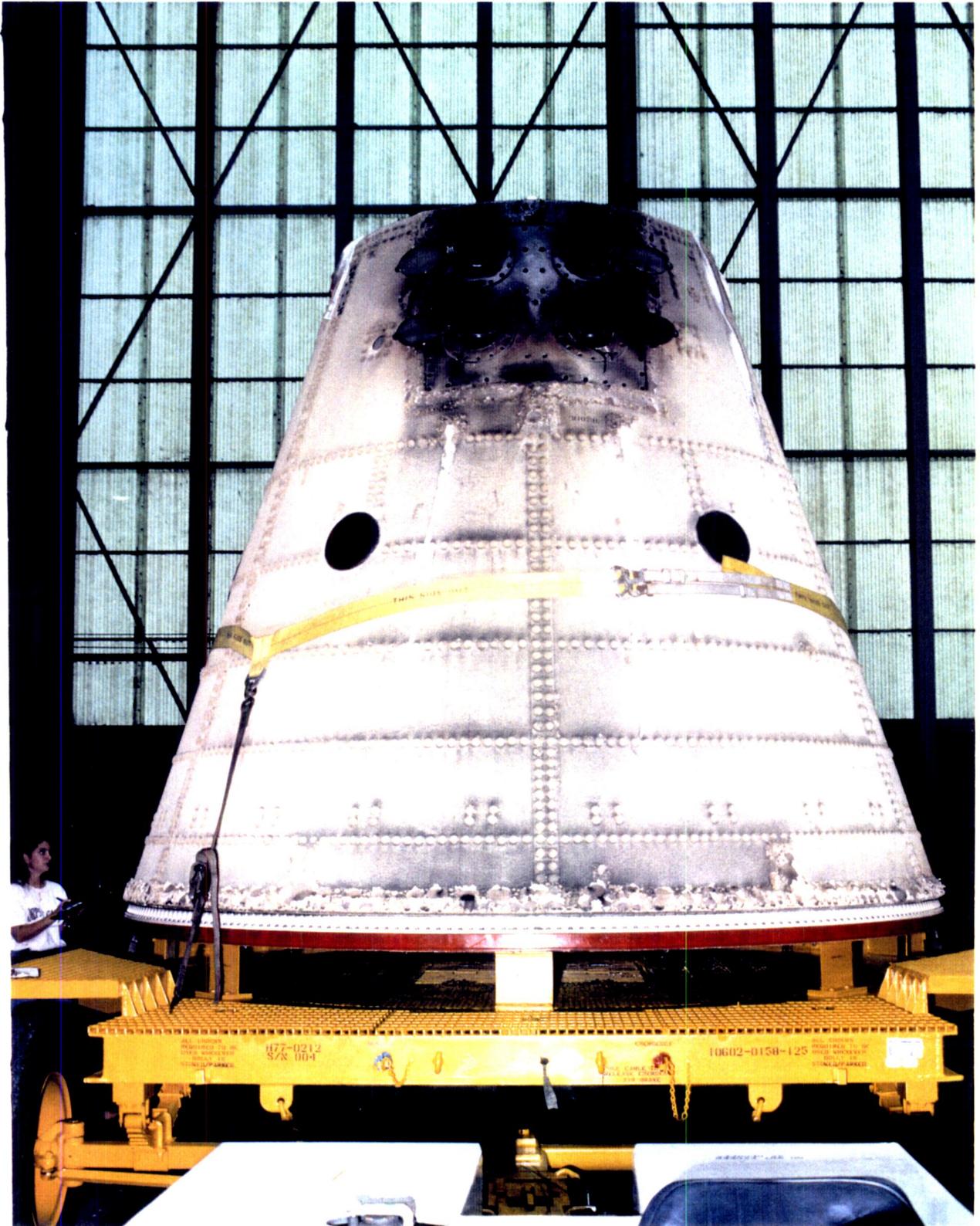


Photo 19 : LH SRB Frustum

The LH frustum was missing no TPS. The number of MSA-2 debonds (28) over fasteners was average. Hypalon paint was blistered/missing along the XB-395 ring frame where BTA closeouts had been applied. The BSM aero heat shield covers had locked in the fully opened position.

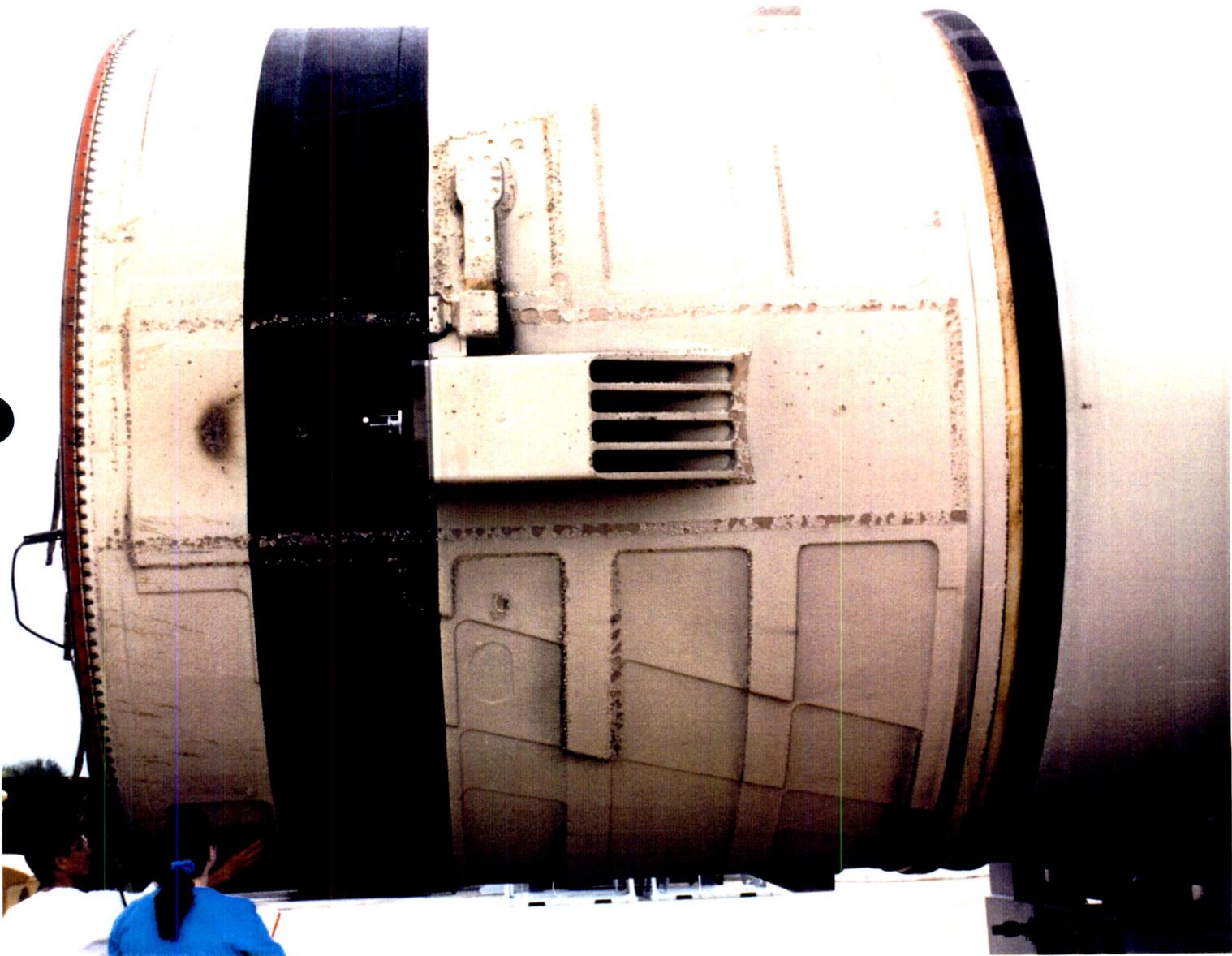


Photo 20 : LH Forward Skirt



Photo 21 : LH Aft Booster/ Aft Skirt

Two 5"x2" MSA-2 divots were present over aft skirt fastener heads. The divots appeared to expose lightly-sooted substrate. Hypalon paint was blistered/missing over the areas where BTA closeouts had been applied. The HDP Debris Containment System (DCS) plungers were seated and appeared to have functioned properly with the exception of HDP #7. The plunger had been obstructed by a frangible nut half most likely as the result of water impact.

7.0 ORBITER POST LANDING DEBRIS ASSESSMENT

A post landing debris inspection of OV-103 Discovery was conducted 22-24 July 1995 at the Kennedy Space Center on SLF runway 33 and in the Orbiter Processing Facility bay #1. This inspection was performed to identify debris impact damage and, if possible, debris sources. The Orbiter TPS sustained a total of 127 hits, of which 9 had a major dimension of 1-inch or larger. This total does not include the numerous hits on the base heat shield attributed to SSME vibration/acoustics and exhaust plume recirculation. A comparison of these numbers to statistics from 54 previous missions of similar configuration (excluding missions STS-23, 25, 26, 26R, 27R, 30R, and 42, which had damage from known debris sources), indicates the total number of hits was slightly less than average and the total number of hits 1-inch or larger was significantly less than average (reference Figures 3-6).

The following table breaks down the STS-70 Orbiter debris damage by area:

	<u>HITS > 1"</u>	<u>TOTAL HITS</u>
Lower surface	5	81
Upper surface	2	29
Right side	0	4
Left side	0	2
Right OMS Pod	0	4
Left OMS Pod	2	7
TOTALS	9	127

The Orbiter lower surface exhibited a total of 81 tile damage sites, of which 5 had a major dimension of 1-inch or larger. These numbers might indicate minimal problems with ET ice, failed woodpecker damage repairs, and intertank TPS divots during ascent. There were no unusually large or unique hits though most of the damage sites showed signs of thermal erosion typically sustained during reentry.

The tile damage sites aft of the LH2 ET/ORB umbilical, which are believed to be caused by impacts from umbilical ice, were typical in number and size.

No tile damage from micrometeorites or on-orbit debris have been identified to date. A deep hole, 1/16-inch in diameter, near the leading edge of the LH MLG door was not considered to be a micrometeorite hit.

Scorch marks on lower surface tile V070-391035-173 (aft and outboard of the LH NLG door) showed a piece of tape was present on the tile during flight and most likely fell off during reentry.

Main landing gear tires and brakes were in good condition for a landing on the KSC concrete runway. However, four pieces of rubber from the nose landing gear tire were recovered at the 5500 foot marker. The tire was damaged by contact with centerline light cover #4-9 protruding 1/4-inch above the adjacent runway concrete. This particular cover, one of 298 on the runway centerline, is 3/4-inch steel, 12 inches in diameter, and secured with six 3/8-inch bolts recessed into U-shaped cutouts. Filler compound, placed between the cover and the runway concrete, has not been a debris problem. Recent inspections identified nineteen centerline light covers exceeding a 1/8-inch protrusion (program specification). Several plans to correct the problem prior to the STS-69 landing are currently being assessed.

No ice adhered to the payload bay door. Virtually no white residue was observed around the waste water dump nozzles. Small tile damage sites were observed on the leading edge of the LH OMS pod and at the base of the vertical stabilizer. One shallow damage site 2.5-inches long by 2-inches wide was located near the mid point of the vertical stabilizer leading edge.

ET/Orbiter separation devices EO-1, EO-2, and EO-3 functioned nominally. All ET/Orbiter umbilical separation ordnance retention shutters were closed properly. Less than usual amounts of umbilical closeout foam and white RTV dam material adhered to the umbilical plate near the LH2 recirculation line disconnect. Hardware found on the runway included a 1-inch long piece of white RTV below the LH2 ET door, part of a metallic rivet beneath the EO-2 area, and a portion of a 3/8-inch diameter O-ring under the body flap. The rivet and O-ring have not yet been identified as flight hardware.

Orbiter windows #3 and #4 exhibited moderate hazing and streaking. A light haze was present on the other windows. The on-orbit impact site on window #6 was not visible from ground level. The number of damage sites on the window perimeter tiles was observed from a distance (ground level) and may include some previous repairs which typically shake loose during ascent.

Tile damage on the base heat shield was slightly more than usual. The Dome Mounted Heat Shield (DMHS) closeout blankets were intact and generally in good condition with the exception of one torn panel at the 3 o'clock position on SSME #2. Tiles on the vertical stabilizer "stinger" and around the drag chute door were intact and undamaged.

The post landing walkdown of Runway 33 was performed immediately after landing. Flight hardware found on the runway included three Q-felt plugs near the pilot chute and drag chute door (4300 foot marker) and rubber from the right nose wheel tire (5500 foot).

All Orbiter drag chute hardware was recovered and appeared to have functioned normally though a rip in the riser sheathing was noted near the riser-to-Orbiter attach harness.

In summary, the total number of Orbiter TPS debris hits was slightly less than average while the total number of hits 1-inch or larger was significantly less than average when compared to previous missions (Figures 7-8).

Orbiter Post Launch Debris Anomalies are listed in Section 9.

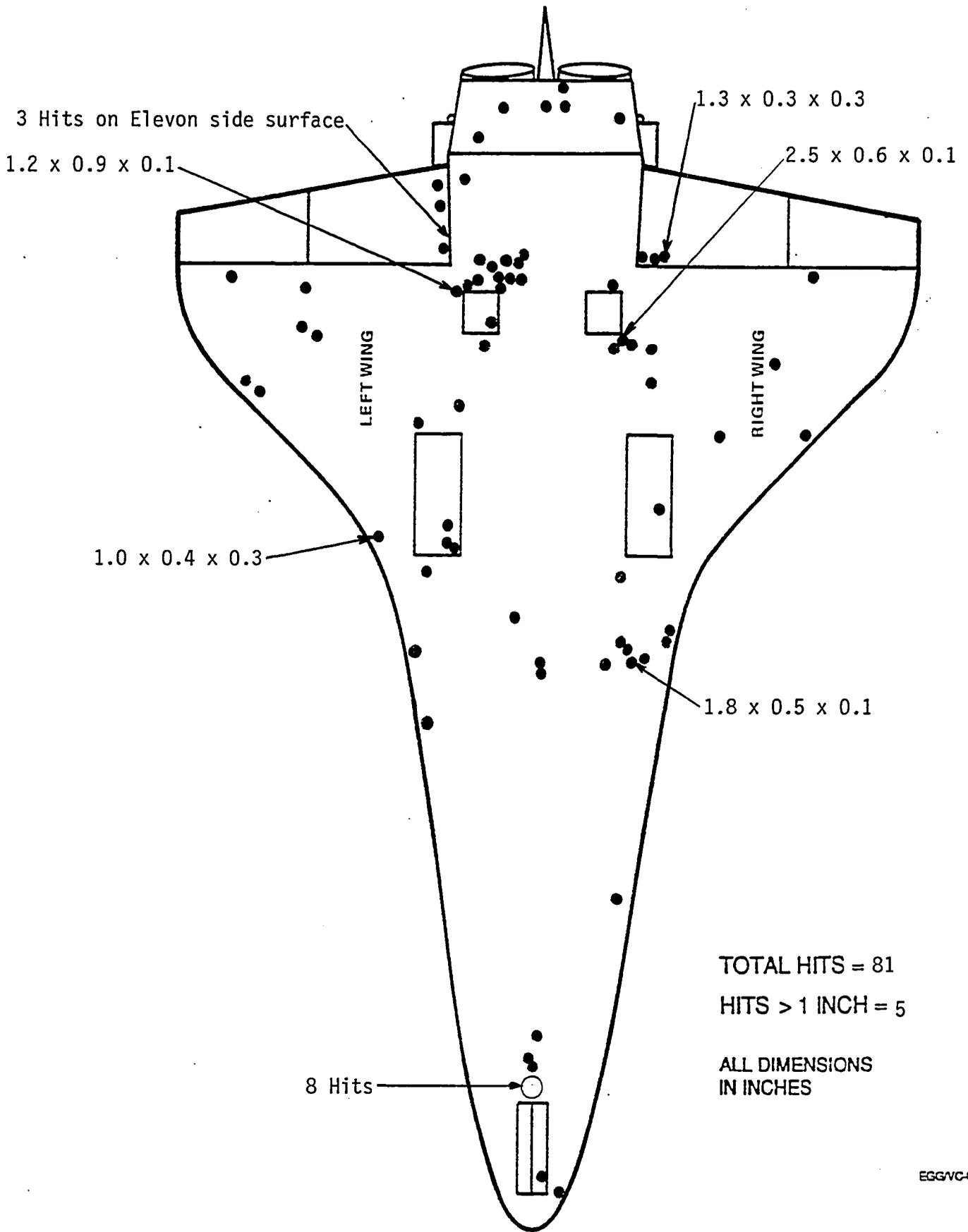
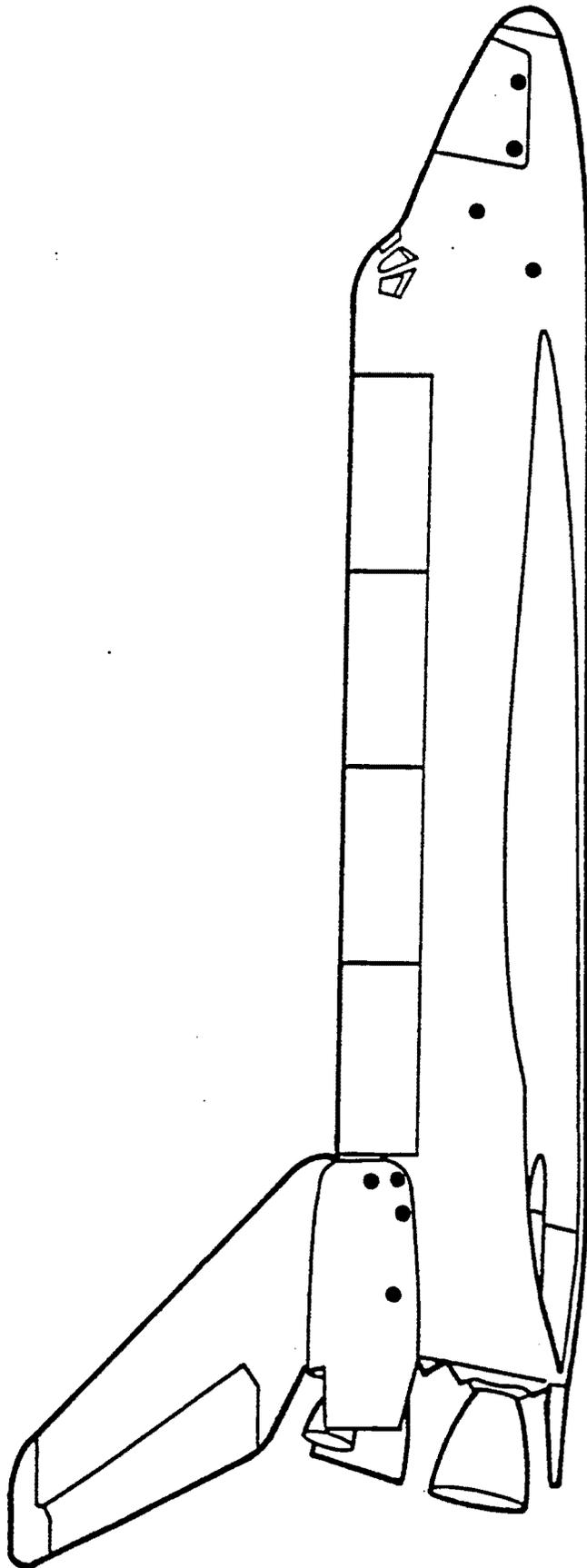


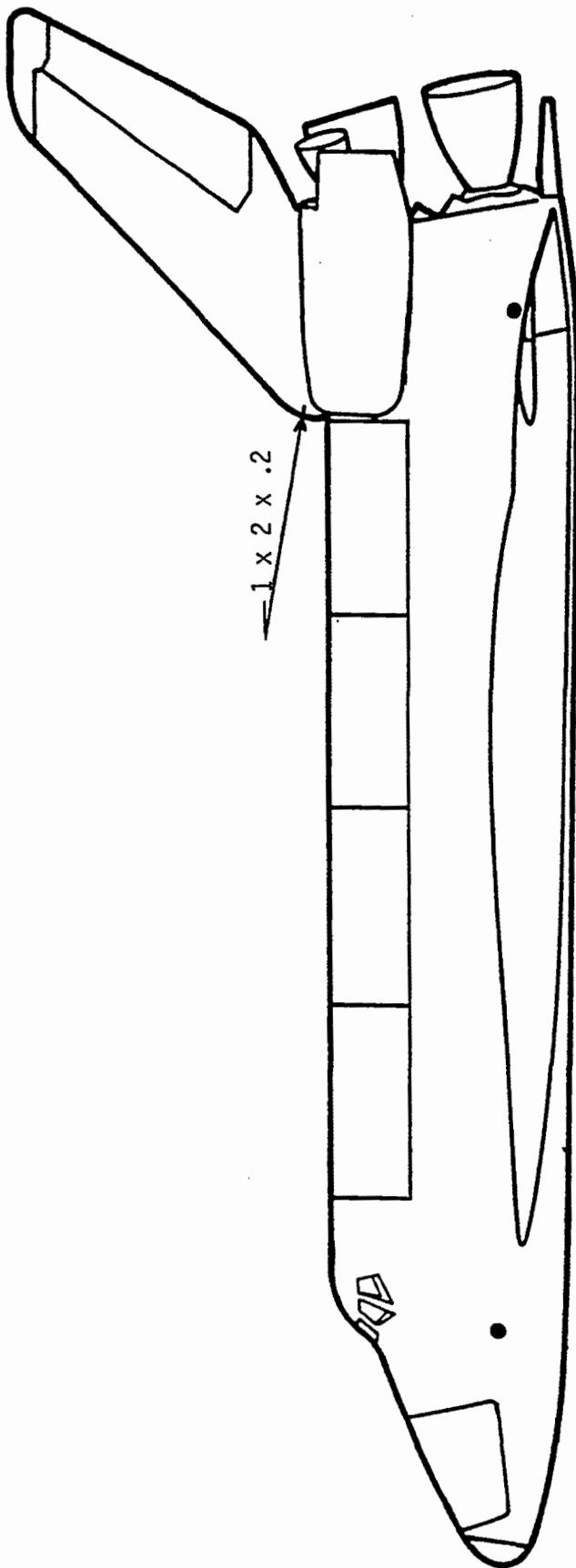
Figure 3 : Orbiter Lower Surface Debris Map



TOTAL HITS = 8
HITS \geq 1 INCH = 0

EGG/V-1-A

Figure 4 : Orbiter Right Side Debris Map



TOTAL HITS = 3
HITS \geq 1 INCH = 1

EGG/V-088

Figure 5 : Orbiter Left Side Debris Map

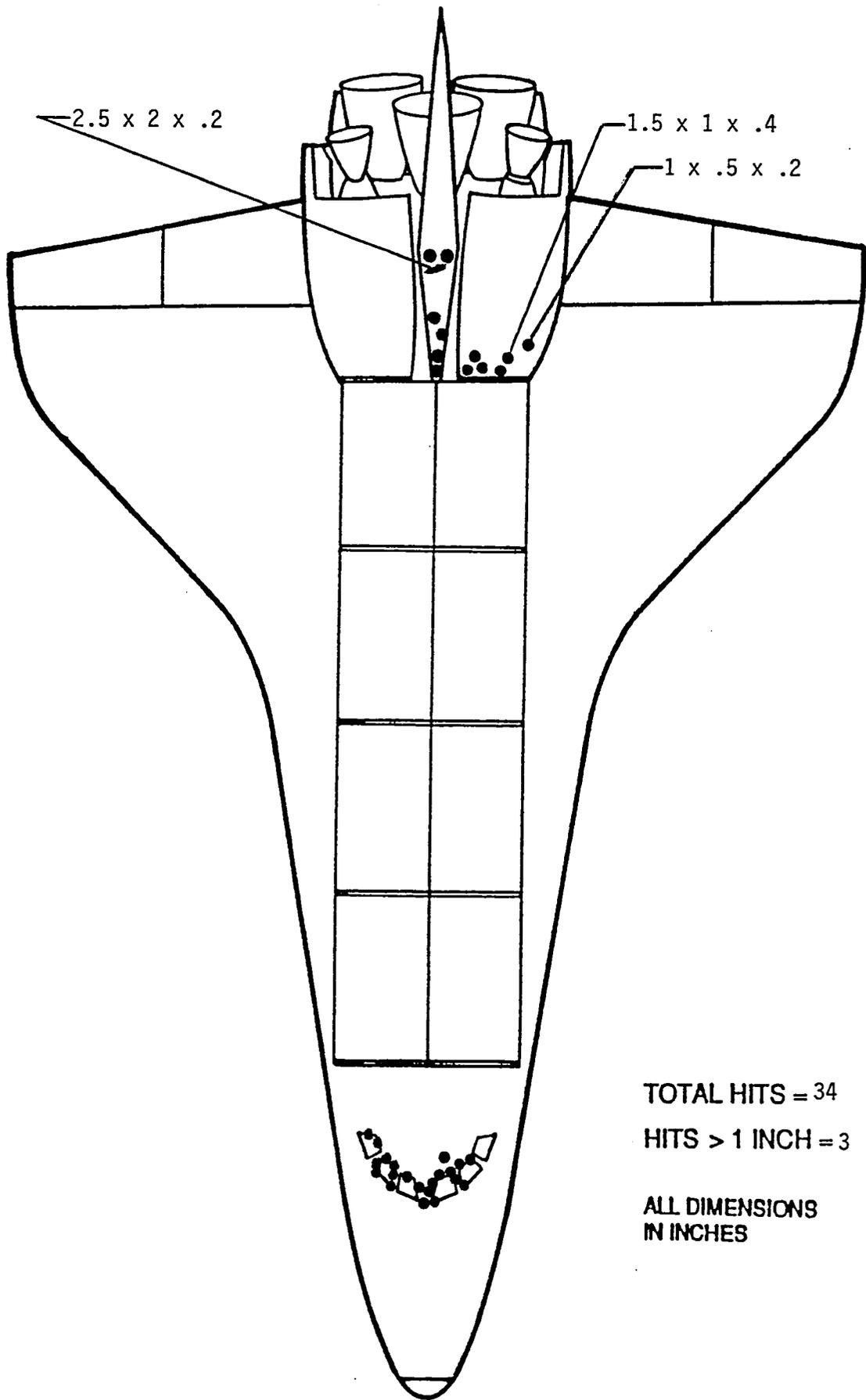


Figure 6 : Orbiter Upper Surface Debris Map

	LOWER SURFACE		ENTIRE VEHICLE	
	HITS > 1 INCH	TOTAL HITS	HITS > 1 INCH	TOTAL HITS
STS-6	15	80	36	120
STS-8	3	29	7	56
STS-9 (41-A)	9	49	14	58
STS-11 (41-B)	11	19	34	63
STS-13 (41-C)	5	27	8	36
STS-14 (41-D)	10	44	30	111
STS-17 (41-G)	25	69	36	154
STS-19 (51-A)	14	66	20	87
STS-20 (51-C)	24	67	28	81
STS-27 (51-I)	21	96	33	141
STS-28 (51-J)	7	66	17	111
STS-30 (61-A)	24	129	34	183
STS-31 (61-B)	37	177	55	257
STS-32 (61-C)	20	134	39	193
STS-29	18	100	23	132
STS-28R	13	60	20	76
STS-34	17	51	18	53
STS-33R	21	107	21	118
STS-32R	13	111	15	120
STS-36	17	61	19	81
STS-31R	13	47	14	63
STS-41	13	64	16	76
STS-38	7	70	8	81
STS-35	15	132	17	147
STS-37	7	91	10	113
STS-39	14	217	16	238
STS-40	23	153	25	197
STS-43	24	122	25	131
STS-48	14	100	25	182
STS-44	6	74	9	101
STS-45	18	122	22	172
STS-49	6	55	11	114
STS-50	28	141	45	184
STS-46	11	186	22	236
STS-47	3	48	11	108
STS-52	6	152	16	290
STS-53	11	145	23	240
STS-54	14	80	14	131
STS-56	18	94	36	156
STS-55	10	128	13	143
STS-57	10	75	12	106
STS-51	8	100	18	154
STS-58	23	78	26	155
STS-61	7	59	13	120
STS-60	4	48	15	106
STS-62	7	36	16	97
STS-59	10	47	19	77
STS-65	17	123	21	151
STS-64	18	116	19	150
STS-68	9	59	15	110
STS-66	22	111	28	148
STS-63	7	84	14	125
STS-67	11	47	13	76
STS-71	24	149	25	164
AVERAGE	14.1	90.6	21.1	131.0
SIGMA	7.2	43.2	9.8	54.7
STS-70	5	81	9	127

MISSIONS STS-23, 24, 25, 26, 26R, 27R, 30R, AND 42 ARE NOT INCLUDED IN THIS ANALYSIS SINCE THESE MISSIONS HAD SIGNIFICANT DAMAGE CAUSED BY KNOWN DEBRIS SOURCES

Figure 7 : Orbiter Post Flight Debris Damage Summary

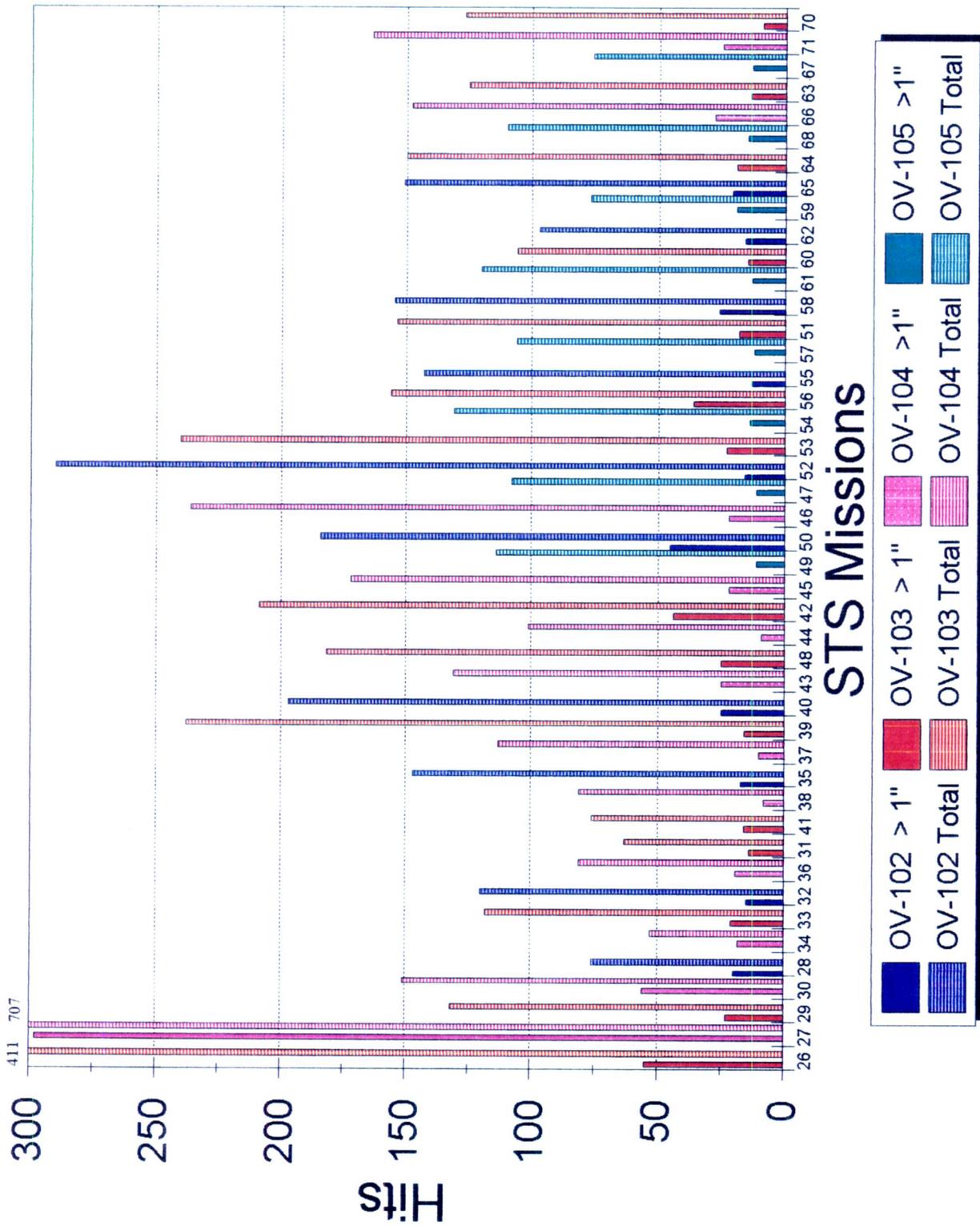


Figure 8 : Orbiter Debris Damage Comparison Chart



Photo 22 : Overall View of Orbiter Right Side

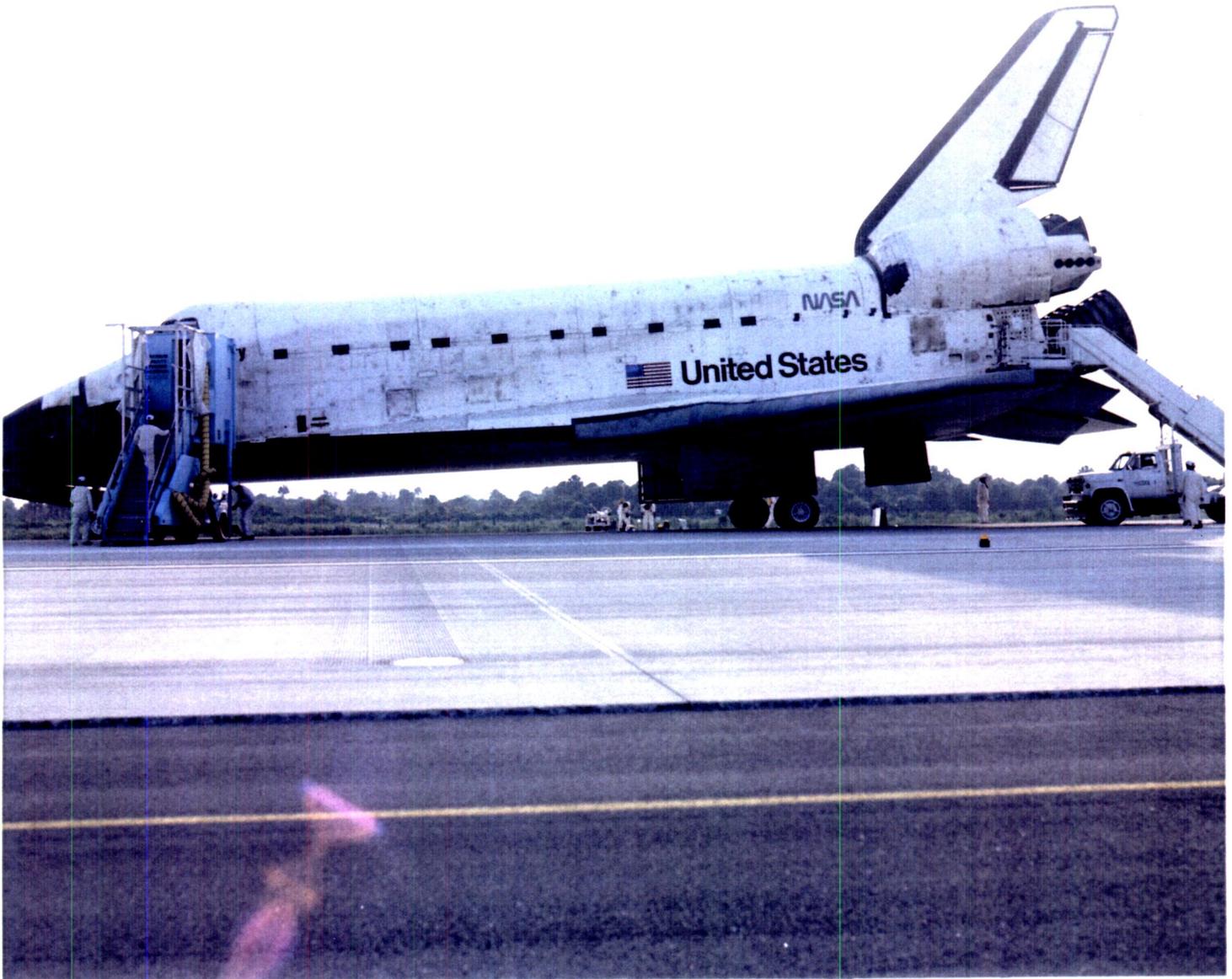


Photo 23 : Overall View of Orbiter Left Side

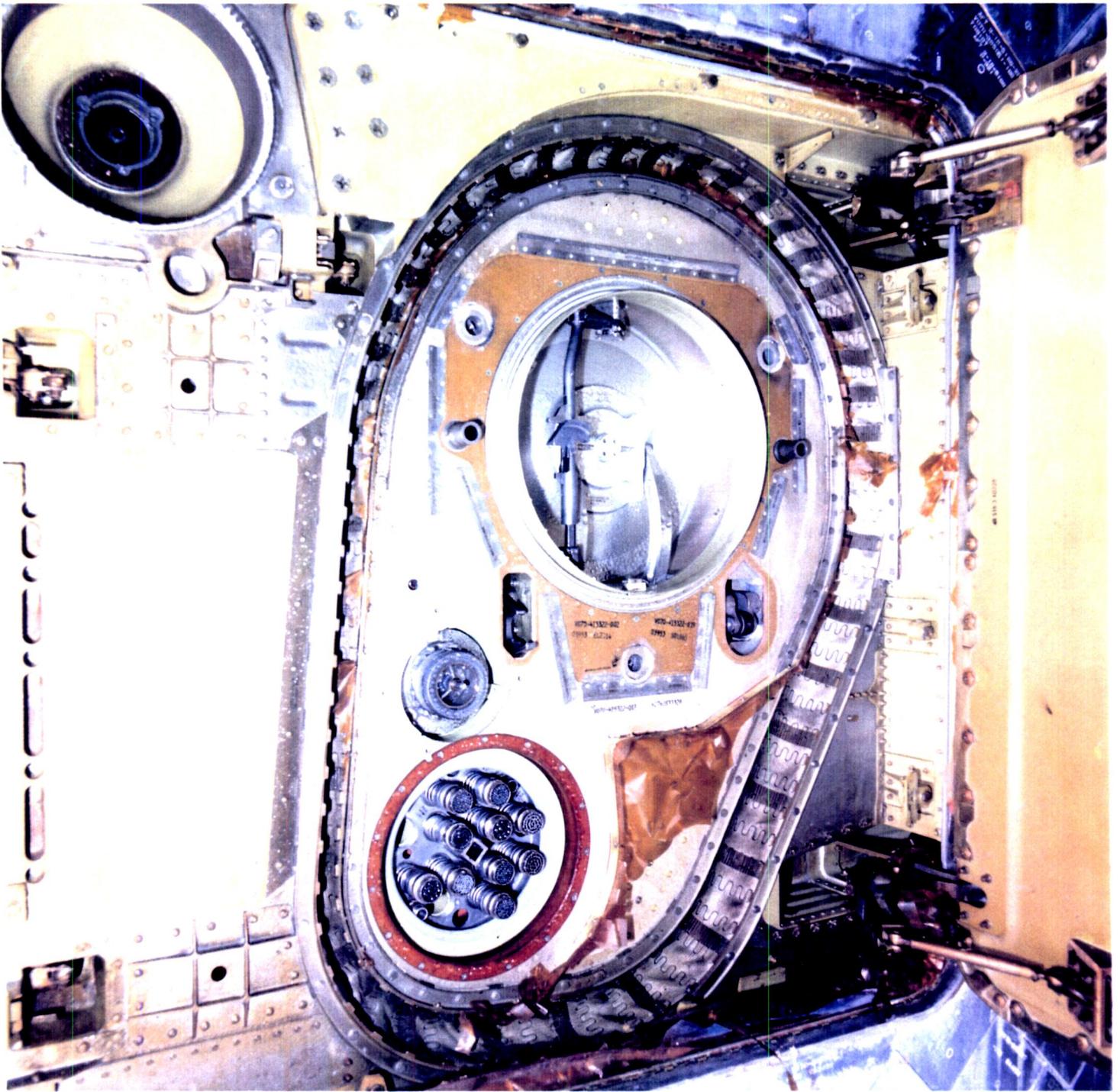


Photo 24 : LO2 ET/ORB Umbilical

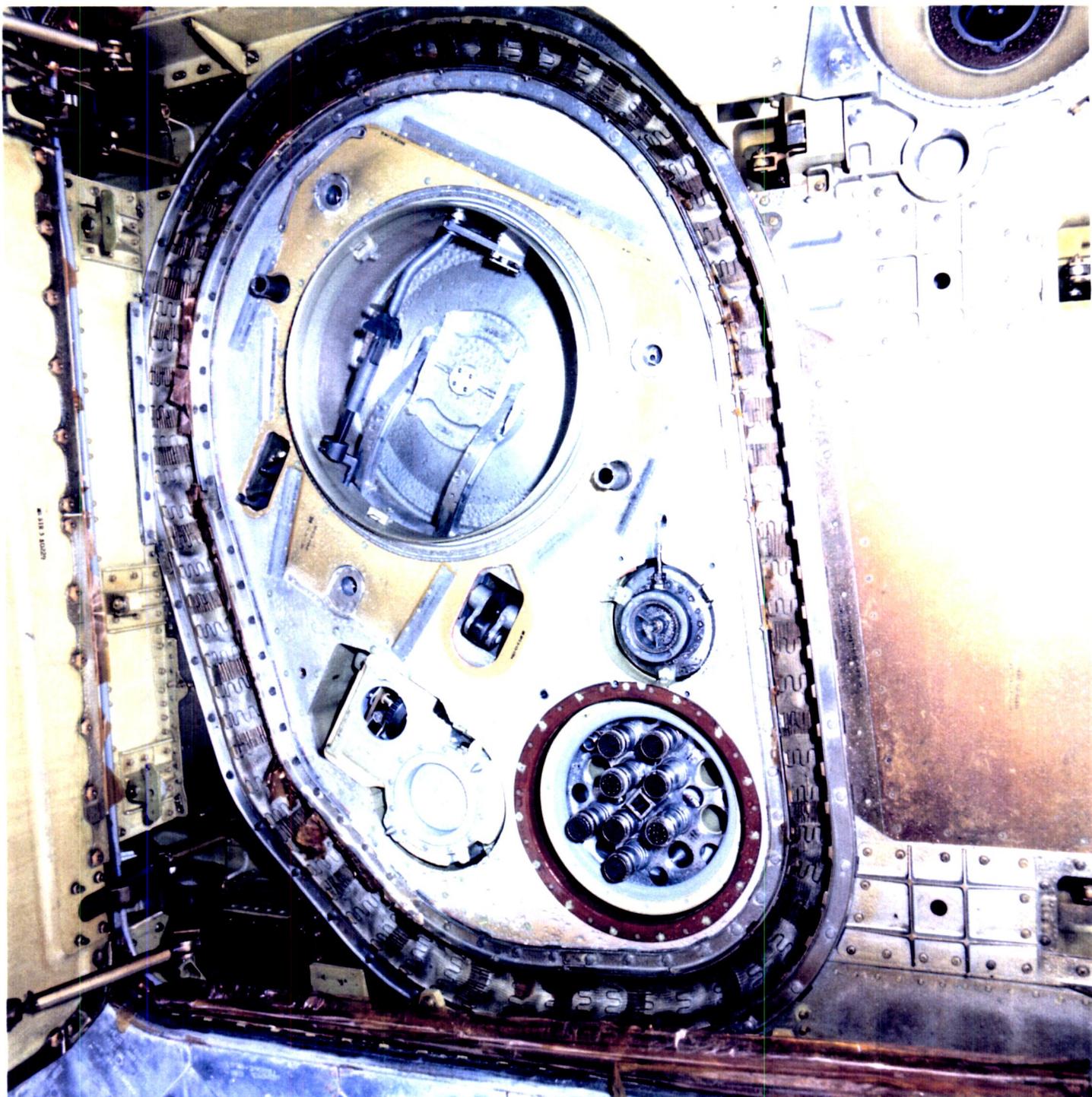


Photo 25 : LH2 ET/ORB Umbilical



Photo 26 : Debris on Runway

Hardware found on the runway included a 1-inch long piece of white RTV below the LH2 ET door, part of a metallic rivet beneath the EO-2 area, and a portion of a 3/8-inch diameter O-ring under the body flap. The rivet and O-ring have not yet been identified as flight hardware.

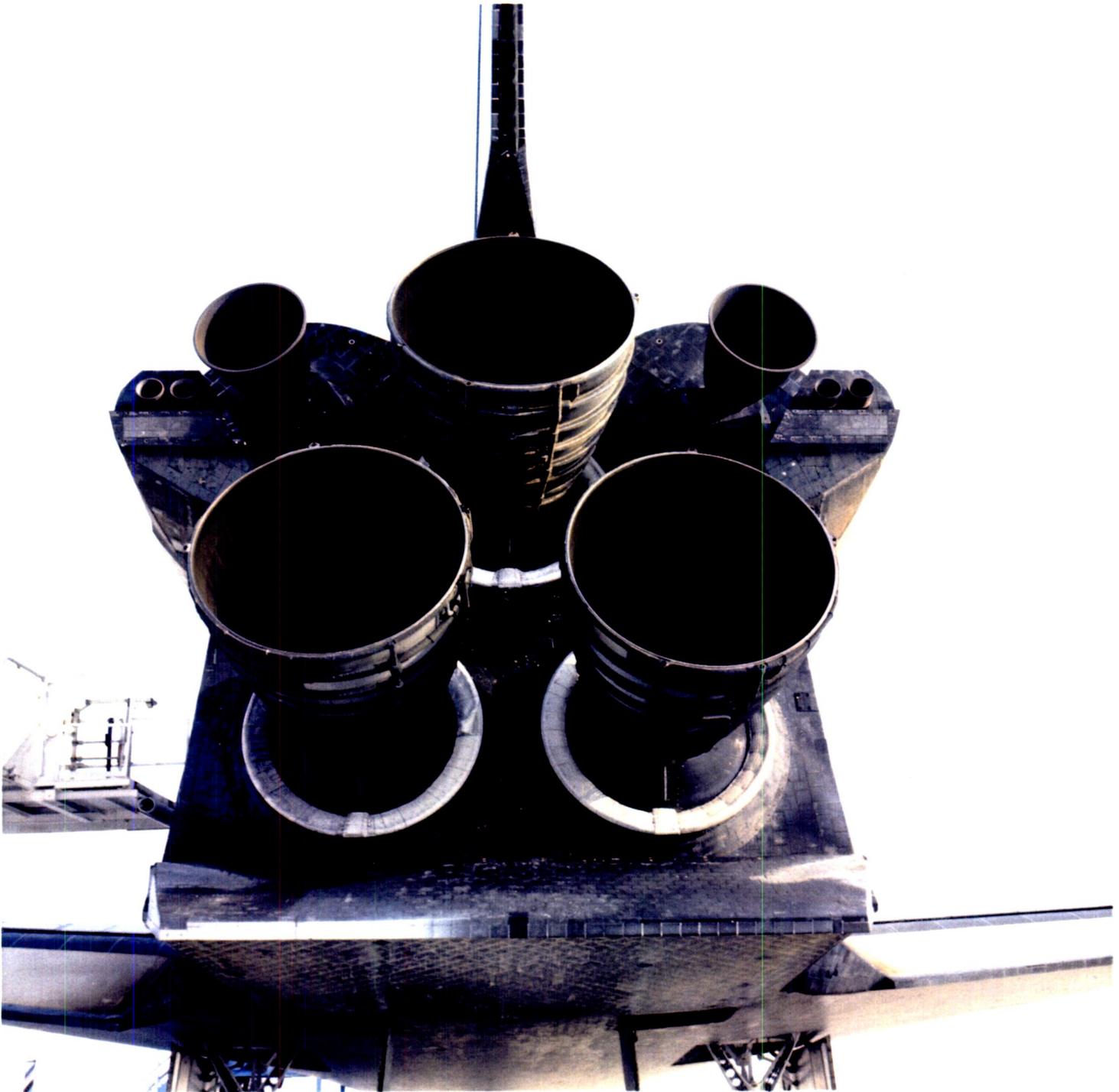


Photo 27 : Base Heat Shield

Tile damage on the base heat shield was slightly more than usual. The Dome Mounted Heat Shield (DMHS) closeout blankets were intact and generally in good condition with the exception of one torn panel at the 3 o'clock position on SSME #2.

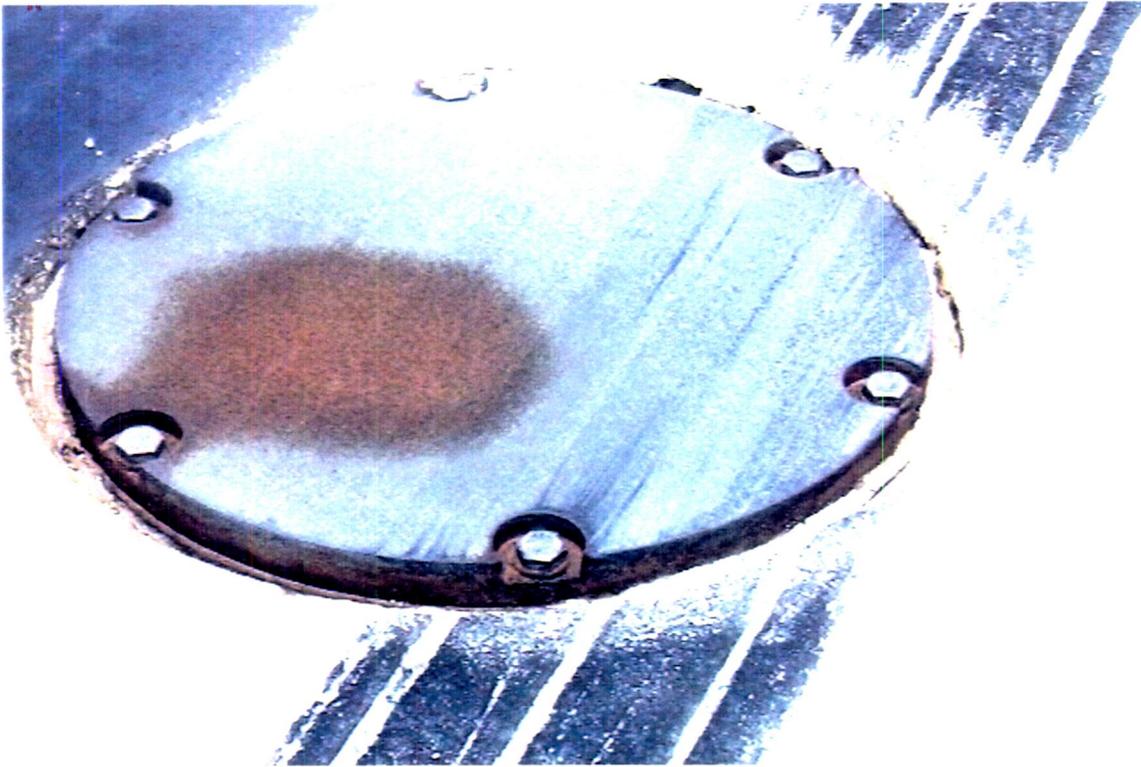


Photo 28 : Nose Gear Tire Damage

The nose landing gear tire was damaged by contact with centerline light cover #4-9 protruding 1/4-inch above the adjacent runway concrete. Recent inspections identified nineteen centerline light covers exceeding a 1/8-inch protrusion (program specification).

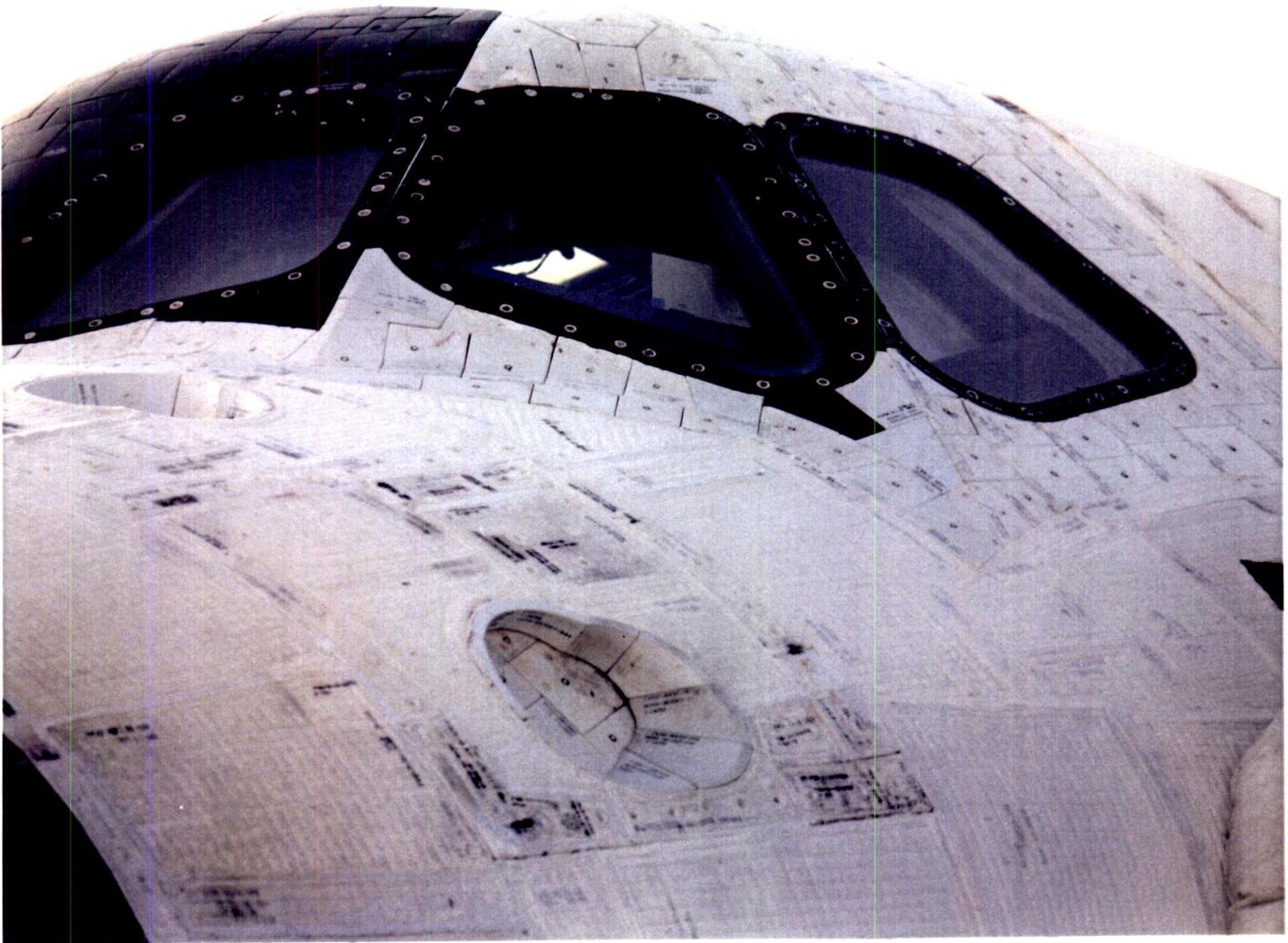


Photo 29 : Orbiter Windows

Orbiter windows #3 and #4 exhibited moderate hazing and streaking.
A light haze was present on the other windows.

8.0 DEBRIS SAMPLE LAB REPORTS

A total of eight samples were obtained from OV-103 Discovery during the STS-70 post landing debris assessment at Kennedy Space Center. The submitted samples consisted of 8 wipes from Orbiter windows #1-8. The samples were analyzed by the NASA KSC Microchemical Analysis Branch (MAB) for material composition and comparison to known STS materials. Debris analysis involves both the placing and the correlating of particles and residues with respect to composition, thermal (mission) effects, and availability. Debris sample results/analyses are listed by Orbiter location in the following summaries.

8.1 ORBITER WINDOWS

Samples from the Orbiter windows indicated exposure to facility environment, SRB BSM exhaust (metallic particulate), landing site materials (earth minerals), Orbiter Thermal Protection System (RTV, tile repair, and glass insulation), Orbiter RCS nozzle cover adhesive, building type insulation, paints and primer from various sources. There was no apparent vehicle damage related to these residuals.

8.2 ORGANIC ANALYSIS

The results of the STS-70 organic analysis are pending.

8.3 NEW FINDINGS

This set of post-flight debris residual samples led to no new findings, although the variety of residual material continues to be representative of that documented in previous mission sampling (Reference Figure 9).

52 Figure 9 : Orbiter Post Landing Microchemical Sample Results

STS	Sample Location				
	Windows	Wing RCC	Lower Tile Surface	Umbilical	Other
70	Metallics - Fac. Env./BSM Residue (SRB) RTV, Tile filler (ORB TPS) Insulation glass (ORB TPS) Earth minerals Building type insulation Organics RTV - RCS thruster nozzle cover adhesive Paint and primer				
71	Metallics - Fac. Env./BSM Residue (SRB) RTV, Tile, Tile filler (ORB TPS) Insulation Glass (ORB TPS) Earth minerals (landing site) Organics - Plastic polymers RTV - RCS thruster nozzle cover adhesive Paint and primer				
67	Metallics - Fac. Env./BSM Residue (SRB) Tile, Tile filler (ORB TPS) Insulation Glass (ORB TPS) Fiber - sample cloth Earth minerals (landing site) Organics - RTV, Plastic polymers Paint and primer				SRB sealant sample: laboratory reference
63	Metallics - Fac. Env./BSM Residue (SRB) RTV, Tile, Tile filler (ORB TPS) Insulation Glass (ORB TPS) Building type insulation Fiber-sample cloth Earth minerals (Landing site) Organics-Plastic polymers, SRB sealant RTV-RCS thruster nozzle cover Paint and primer		Silica-rich tile(ORB TPS) Hypalon paint (SRB)		
66	Metallics - Fac. Env./BSM Residue (SRB) RTV, Tile, Tile filler (ORB TPS) Insulation Glass (ORB TPS) Fiber-sample cloth Earth minerals (Landing site) Organics-Plastic polymers, SRB sealant RTV-RCS thruster nozzle cover Paint and primer		Silica-rich tile (ORB-TPS) Hypalon paint (SRB)		

For data on previous missions refer to mission reports prior to STS-59

9.0 POST LAUNCH ANOMALIES

Based on the debris walkdowns and film/video review, 5 post launch anomalies, but no In-Flight Anomalies (IFA's), were observed on the STS-70 mission.

9.1 LAUNCH PAD/SHUTTLE LANDING FACILITY

1. The loose bolt on the E-16 camera housing/mount was still attached to the housing after launch.
2. A 2-inch by 3/4-inch spring, believed to be from the facility rather than the GUCP, was found laying in the ground umbilical carrier assembly near electrical connector J2.

9.2 SOLID ROCKET BOOSTERS

1. A large piece of aft skirt instafoam, approximately 18 inches long by 10 inches wide by 10 inches thick, stuck to the RH SRB aft skirt purge line as the vehicle lifted off holddown post #2.
2. The BSM aft attach bracket adjacent to HDP #1 was missing K5NA to substrate.

9.3 EXTERNAL TANK

1. No items.

9.4 ORBITER

1. Main landing gear tires and brakes were in good condition for a landing on the KSC concrete runway. However, four pieces of rubber from the nose landing gear tire were recovered at the 5500 foot marker. The tire was damaged by contact with centerline light cover #4-9 protruding 1/4-inch above the adjacent runway concrete. This particular cover, one of 298 on the runway centerline, is 3/4-inch steel, 12 inches in diameter, and secured with six 3/8-inch bolts recessed into U-shaped cutouts. Filler compound, placed between the cover and the runway concrete, has not been a debris problem. Recent inspections identified nineteen centerline light covers exceeding a 1/8-inch protrusion. Several plans to correct the problem prior to the STS-69 landing are currently being assessed.

APPENDIX A. JSC PHOTOGRAPHIC ANALYSIS SUMMARY



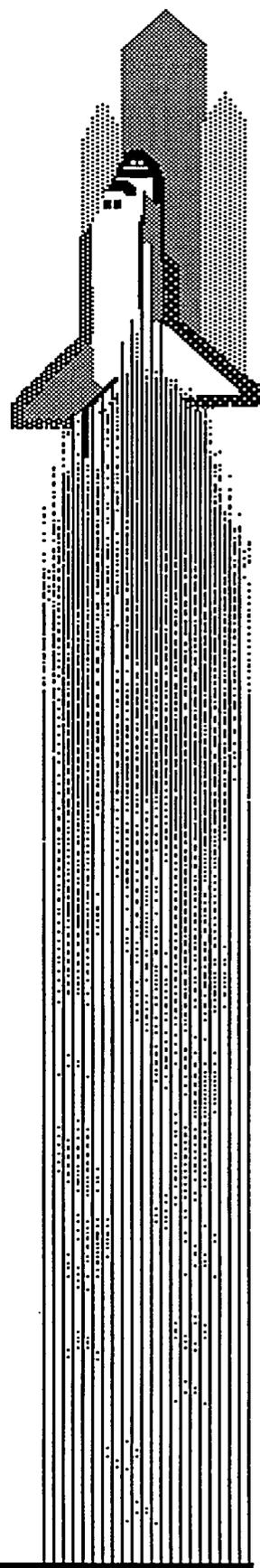
Space Shuttle

Earth Science Branch

Image Science and
Analysis Group

STS-70 Summary of Significant Events

August 21, 1995





**Space Shuttle
Image Science and
Analysis Group**

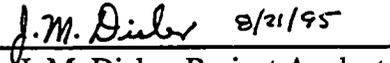
STS-70 Summary of Significant Events

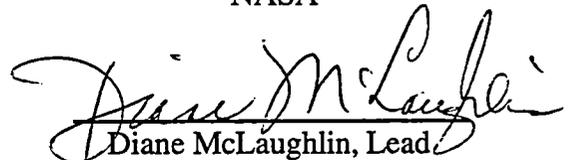
Project Work Order - SN-52V

Approved By

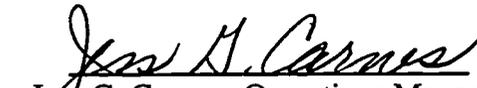
Lockheed

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1. STS-70 (OV-103): Film/Video Screening and Timing Summary

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1. STS-70 (OV-103): Film/Video Screening and Timing Summary

1. STS-70 (OV-103): FILM / VIDEO SCREENING AND TIMING SUMMARY

1.1 SCREENING ACTIVITIES

1.1.1 Launch

Discovery (OV-103) launched on mission STS-70 from pad B at 13:41:55.027 Coordinated Universal Time (UTC) on Thursday, July 13, 1995 (day 194) as seen on camera E8. Solid rocket booster (SRB) separation occurred at 13:43:57.784 UTC as seen on camera E207.

On launch day, 23 of 24 expected videos were screened, (ET208 was not received). Following launch day, 53 films were reviewed. No potential anomalies were observed during launch.

Detailed Test Objective (DTO-312), photography of the external tank after separation, was performed using the handheld Nikon camera with a 300 mm lens and 2x extender. Thirty-seven excellent quality views were acquired. No external tank anomalies were seen. No unusual markings due to the TPS repairs were noted. Orbiter umbilical well films were not acquired (OV-103 is not equipped with umbilical cameras).

1.1.2 On Orbit

Analysis of a micrometeoroid debris impact of the Orbiter number "6" (starboard) window was done at the request of the MER. An enhanced image of the impact crater was sent to the MER. No follow-up action was requested.

1.1.3 Landing

Discovery landed on runway 33 at KSC on Saturday, July 22, 1995. Twelve videos of the Orbiter's approach and landing were received.

No major anomalies were noted in any of the approach, landing, and roll-out video views screened.

1. STS-70 (OV-103): Film/Video Screening and Timing Summary

1.2 TIMING ACTIVITIES

Launch:

Video ET207 had incorrect timing. Film camera E220 did not have timing, and E222 had incorrect timing. Film cameras: E1, E2, E3, E4, E5, E6, E7, E8, E9, E10, E11, E12, E13, E14, E15, E16, E17, E18, E19, E20, E25, E26, E30, E33, E34, E35, E36, E40, E50, E52, E54, E57, E59, E60, E62, E63, E65, E76, E77, E79, and E224 had in-frame alphanumeric timing. The time codes from videos and films were used to identify specific events during the initial screening process. The remaining launch films had coded IRIG time at the edge of the film. Table 1.2.1 provides the events that were timed.

Event Description	Time (UTC)	Camera
Launch	194:13:41:55.027	E8
Condensation - Start	194:13:42:35.170	KTV21B
Condensation - End	194:13:42:49.885	KTV21B
Recirculation - Start	194:13:43:27.494	ET212
Recirculation - End	194:13:43:39.239	ET212
SRB Separation	194:13:43:57.784	E207

Table 1.2.1: Launch Film and Video Timing Events

Landing:

Twelve videos were screened on landing day. Eleven videos: KTV5, KTV6, KTV11, KTV12, KTV13, KTV15, KTV20L, KTV33, SLF South, EL17, and EL18 had timing. There was no IRIG timing for the SLF North video.

Event Description	Time (UTC)	Camera
Landing gear - doors opened	203:12:01:39.405	KTV6
<i>Touchdown</i>		
Left Main Wheel	203:12:01:59.430	SLF-South
Right Main Wheel	203:12:01:59.530	SLF-South
Nose Wheel	203:12:02:08.519	KTV33
Wheel stop	203:12:02:58.984	KTV15

Table 1.2.2: Landing Video Timing Events

2. STS-70 (OV-103): Summary of Significant Events

2. SUMMARY OF SIGNIFICANT EVENTS

2.1 DEBRIS

2.1.1 Debris Near the Time of SSME Ignition

2.1.1.1 LH2 and LO2 ET/Orbiter Umbilical Disconnect Debris

(Cameras: OTV109, OTV154, OTV161, OTV163, E1, E4, E5, E6, E16, E25, E26, E30, E31, E34, E40, E41, E52, E62, E65)

Normal ice debris was noted falling from the LH2 and LO2 ET/Orbiter umbilical disconnect areas at SSME ignition through liftoff. A small light colored piece of debris appeared to strike the Orbiter umbilical well door sill after SSME start-up (T-3.171). No damage to the shuttle launch vehicle was seen. No follow-up action was requested.

2.1.2 Debris Near the Time of SRB Ignition

2.1.2.1 SRB Flame Duct Debris

(Cameras: E1, E3, E7, E8, E9, E12, E13, E14, E15, E16, E60, E63)

As on previous missions, debris was noted originating from the SRB flame duct area after SRB ignition. A single piece of light colored debris (probably from the SRB flame duct) was seen north of the MLP at liftoff. A single light colored piece of debris was seen moving from the exhaust cloud at the north end of the MLP toward the Shuttle Launch Vehicle at liftoff (0.7 seconds MET). This debris was not seen to contact the launch vehicle. Several red colored pieces of debris (possibly flame duct water baffle material) were seen near the RSRB holddown posts M-3 and M-4 at liftoff (1.1 seconds MET). No follow-up action was requested.

2.1.2.2 LH2 and LO2 Tail Service Mast (TSM) T-0 Umbilical Disconnect Debris (Cameras: OTV149, OTV150, E17, E18, E19, E20, E31, E63, E76, E77)

Normal ice debris was noted falling from the LH2 and LO2 TSM T-0 umbilical disconnect areas at liftoff. None of the debris was observed to strike the vehicle. No follow-up action was requested.

2.1.2.3 GH2 Vent Arm Debris During Disconnect and Retraction (Cameras: E33, E34, E35, E50, E54, E59, E60)

As on previous missions, vapor and multiple light colored pieces of ice debris fell from the GH2 vent arm carrier plate at vent arm retraction. The GH2 vent arm retraction appeared normal.

2.1.2.4 Upward Moving Debris (Camera: OTV109)

A small light colored piece of debris traveled up between the body flap and the SSME bells after SSME ignition (T-5.907). The debris was not seen to contact the shuttle launch vehicle. No follow-up action was requested.



1. STS-70 (OV-103): Film/Video Screening and Timing Summary

2.1.3 Debris After Liftoff

Multiple pieces of debris were seen falling aft of the Shuttle Launch Vehicle (SLV) at liftoff, throughout the roll maneuver and beyond, on the launch tracking views. Most of the debris was probably reaction control system (RCS) paper or ice from the ET/Orbiter umbilicals. No follow-up action was requested.

2.1.3.1 Debris at 1.1 to 2.2 seconds MET

(Cameras: E1, E63, E77)



Figure 2.1.3.1 Debris Seen Near the Orbiter Right Wing Tip

A single dark colored piece of debris was seen near the Orbiter right wing tip moving in a westerly direction at liftoff. This debris fell aft into the exhaust cloud and was not seen to contact the launch vehicle (Figure 2.1.3.1). No follow-up action was requested.

2.1.3.2 Debris at 1.4 seconds MET

(Camera: E15)

Several thin, dark pieces of debris were seen by the RSRB holddown post M-4 at liftoff. The debris was not seen to contact the launch vehicle.

2.1.3.3 Debris at 2.1 seconds MET

(Camera: E65)

A small piece of light colored debris was seen falling along the ET TPS near the LO2 feedline at liftoff. This debris was not seen to contact the launch vehicle.

1. STS-70 (OV-103): Film/Video Screening and Timing Summary

2.1.3.4 Debris at 2.3 seconds MET (Camera: E1)

A dark piece of debris was seen moving toward the SRB flame duct at liftoff.

2.1.3.5 Debris at 2.8 to 3.3 seconds MET (Cameras: E3, E63, E77)

Two large pieces of dark debris were seen near the LO2 TSM in the exhaust cloud after liftoff.

2.1.3.6 Debris at 4.3 seconds MET (Camera: OTV161)

Two light colored pieces of debris fell aft of the launch vehicle after tower clear (probably RCS paper or umbilical well ice debris).

2.1.3.7 Debris at 16 through 17 seconds MET (Cameras: E52, E213, E222)

Several light colored pieces of debris (possibly ET/Orbiter umbilical baggy material) was seen aft of the Shuttle launch vehicle after the roll maneuver between the left and right SRBs.

2.1.3.8 Debris Reported by the Crew (Task #10)

The transcript of the crew debris report is as follows:

Capcom: Tom and Kevin if you have a chance, we are ready to copy your Debris Report if you have one.

Discovery: Standby. Houston Discovery, no debris, especially no feathers. Just the normal hazing from SRB separation.

Capcom: OK Tom we copy that.

The End.

1. STS-70 (OV-103): Film/Video Screening and Timing Summary

2.2 MOBILE LAUNCH PLATFORM (MLP) EVENTS

2.2.1 Orange Vapor (Cameras: OTV170, OTV171)

Orange vapor (possibly free burning hydrogen) was seen near the base and above the rim of SSME #1 just prior to SSME start-up (T-5.2 seconds). Orange vapors in the vicinity of the SSMEs just prior to SSME start-up has been seen on previous mission films and videos. No follow-up action was requested.

2.2.2 Flexing of the Orbiter Base Heat Shield (Camera: E76)

Flexing of the Orbiter base heat shield was seen between the SSME cluster at SSME ignition. Flexing of the base heat shield has been seen on previous missions. No follow-up action was requested.

2.2.3 Base Heat Shield Erosion (Cameras: E17, E18, E19, E20)

Slight erosion of the tile surface coating material was seen on the base heat shield and the bases of the right and left RCS stingers at SSME start-up. Heat shield erosion has been seen on previous missions. No follow-up action was requested.

2.2.4 Orange Colored Flash (Camera: E77)

An orange colored flash was seen in the SSME #1 exhaust plume prior to liftoff at T-0.145 seconds MET. This event has been seen on previous missions. No follow-up action was requested.

1. STS-70 (OV-103): Film/Video Screening and Timing Summary

2.2.5 Large Piece of Aft Skirt Instafoam (Camera: E8)

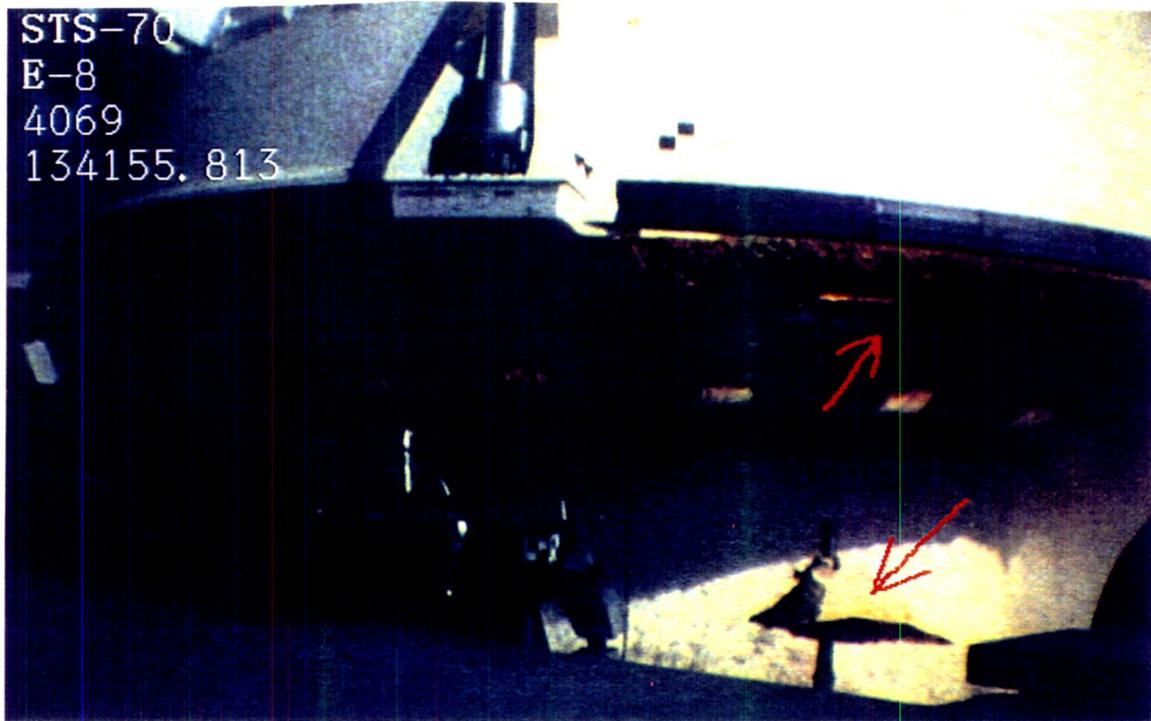


Figure 2.2.5 (A) Aft Skirt Instafoam Attached to the RSRB GN2 Purge Line

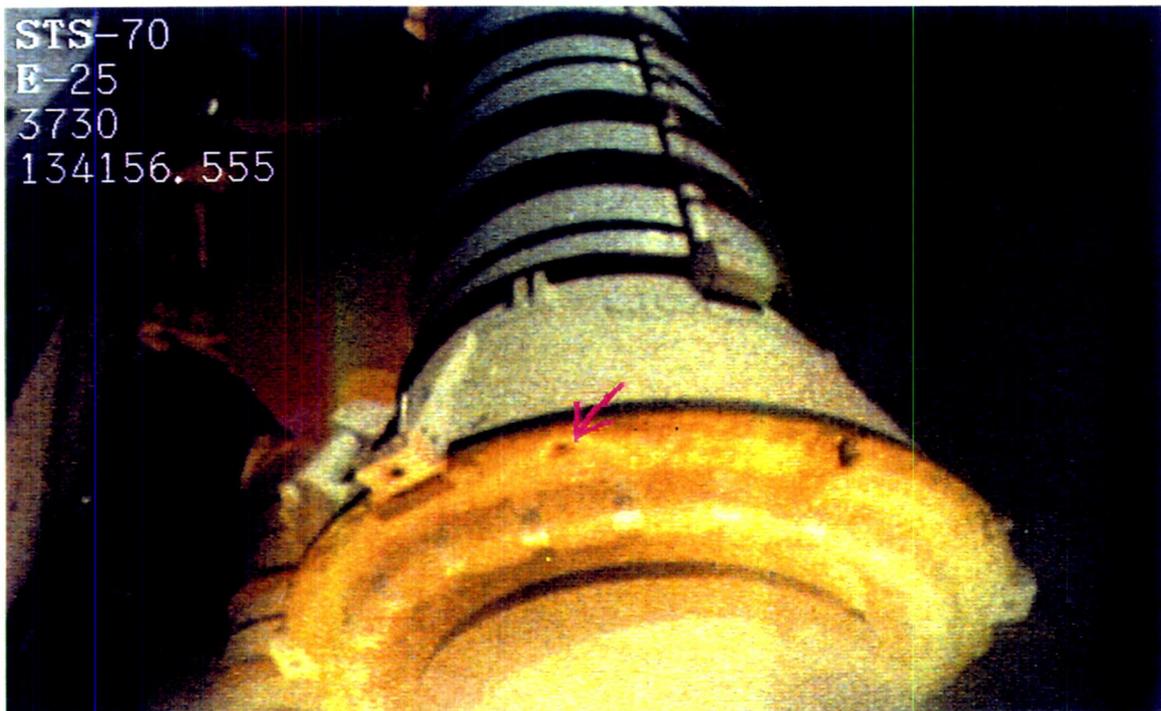


Figure 2.2.5 (B) Missing Instafoam on the RSRB Aft Skirt

1. STS-70 (OV-103): Film/Video Screening and Timing Summary

A large piece of aft skirt instafoam remained attached to the RSRB GN2 purge line near holddown post #2 at liftoff (Figure 2.2.5 A, lower arrow). The missing instafoam on the RSRB aft skirt could be seen on cameras E5, E8 and E25 (Figure 2.2.5 B and Figure 2.2.5 A, upper arrow). No follow-up action was requested.

2.2.6 RSRB HPU Venting (Camera: E52)

Venting from the RSRB Hydraulic Power Unit (HPU) exhaust port was visible during liftoff. No follow-up action was requested.

2.3 ASCENT EVENTS

2.3.1 Body Flap Motion (Task #4)

Slight body flap motion was observed prior to liftoff and during ascent. Photographic analysis of the body flap motion was performed. Table 2.3.1 is a summary of the body flap motion measurements for STS-70.

Body Flap Motion (max. measured)	Starboard side	Port side	Frequency (global)	Camera
On Launch Pad	0.5"	0.5"	9.0 Hz	E17
During Ascent	-	-	9.0 Hz	E212

Table 2.3.1: Measured Body Flap Motion on the Pad and During Ascent

2.3.1.1 Body Flap Motion on the Pad (Camera: E17)

Several points defining the aft port and starboard edges of the body flap were chosen on every fourth frame over a period of 400 frames. This corresponds to approximately one second of actual data. A control point on the body flap thickness (assumed to lie in the plane of motion) was used as the scaling factor for this analysis. The maximum peak-to-peak motion was measured to be approximately 0.5 inches on the starboard side and 0.5 inches on the port side.

A frequency-domain analysis revealed the existence of several specific modes of vibration. Both the port and starboard sides revealed peaks at 9.0 Hz (global rotation) and the starboard side also revealed peaks at 25.5 Hz (1st bending). This analysis is part of a long term trend analysis (study) on body flap motion.

1. STS-70 (OV-103): Film/Video Screening and Timing Summary

2.3.1.2 Body Flap Motion During Ascent (Camera: E212)

Camera E212 provided the best view of body flap motion seen during ascent. A subjective comparison between this mission and others since reflight indicated slight body flap motion was present on STS-70. Several points defining the aft port and starboard edges of the body flap were chosen on every other frame over a period of 200 frames. This corresponded to approximately three seconds of actual data. In addition, two control points on the Orbiter fuselage were chosen to serve as a control for error measurements. SSME bell diameters (in the plane of motion) were used as scaling factors for this analysis. The maximum peak-to-peak motion was found to be approximately 0.5 inches on the starboard side and 0.5 inches on the port side. However, most of the measured motion can be attributed to the presence of the noise in the data.

A frequency-domain analysis identified specific modes of vibration. Both the port and starboard data revealed peaks at 9.0 Hz (global rotation) and 15 Hz (torsion). However, due to noise dominating many of the higher frequencies, no conclusive results could be obtained from the analysis. The significance of the presence of different modes depends upon the results of a long term trend analysis. Camera defocus problems, atmospheric distortions and measurement errors affected the overall accuracy of these results.

2.3.2 Vapor from the SRB Stiffener Rings (Cameras: KTV21B, E2, E5, E34, E40, E62, E222)

More vapors than usual were seen coming from the SRB Stiffener Rings after liftoff. Vapor from the SRB Stiffener Rings has been seen on previous missions and is considered a normal event. No follow-up action has been requested.

2.3.3 Flares in SSME Exhaust Plume (Cameras: E212, E223)

An orange colored flare was seen in the SSME exhaust plume after liftoff at approximately 39 seconds MET (E223). An orange colored flare was also seen in the SSME exhaust plume at 43.8 seconds MET (E212). Orange colored flares have been seen in the SSME exhaust plume on previous missions. No follow-up action was requested.

1. STS-70 (OV-103): Film/Video Screening and Timing Summary

2.3.4 Condensation (Cameras: E207, E212, E220)

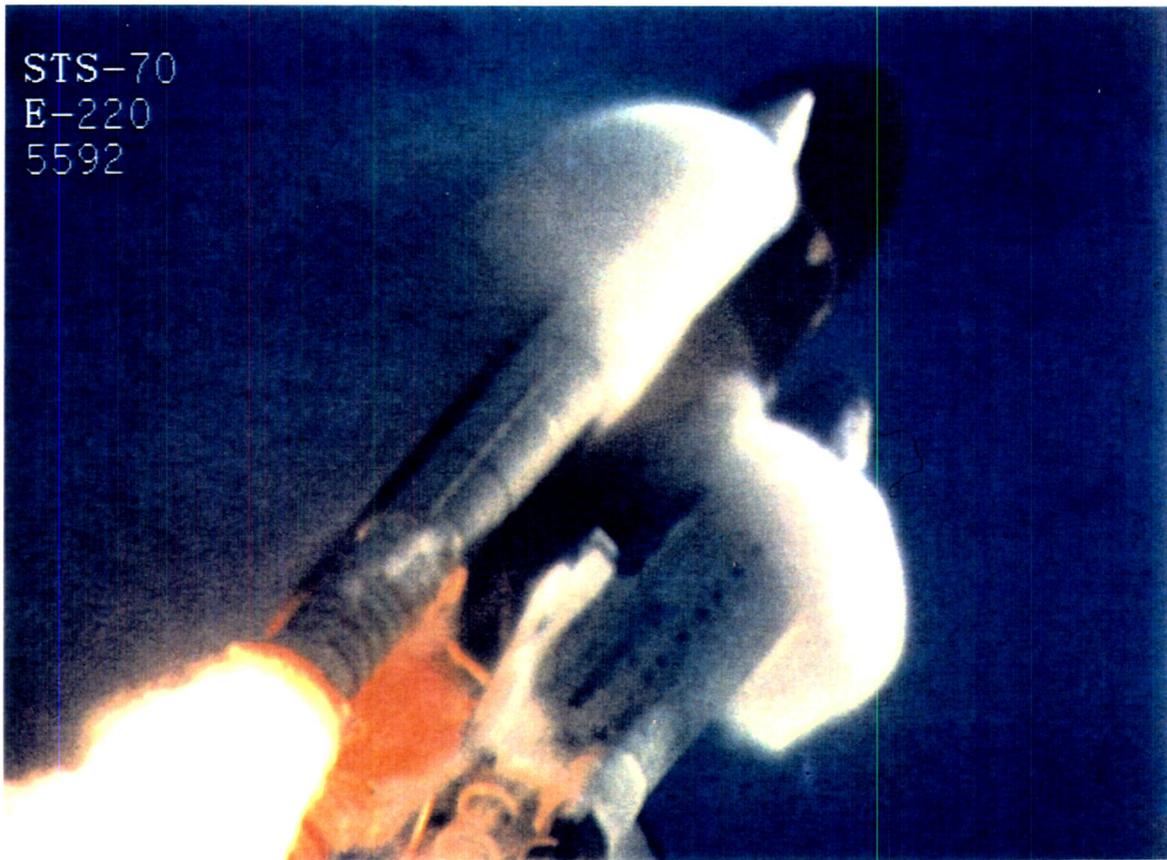


Figure 2.3.4 Condensation Seen Around Shuttle Launch Vehicle

Condensation was seen around the Shuttle Launch Vehicle between 44 and 57 seconds MET.

2.3.5 Recirculation (Task #1) (Cameras: KTV13, E54, E208, E212)

The recirculation or expansion of burning gases at the aft end of the Shuttle Launch Vehicle (SLV) prior to SRB separation has been seen on nearly all previous missions. For STS-70, the start of recirculation was observed at approximately 92 seconds MET and the end was noted at approximately 104 seconds MET. No follow-up action was requested.

1. STS-70 (OV-103): Film/Video Screening and Timing Summary

2.4 ONBOARD PHOTOGRAPHY OF THE EXTERNAL TANK (DTO-312)

2.4.1 Analysis of the STS-70 Handheld External Tank Pictures (Task # 5)

DTO-312 photography of the STS-70 external tank (after separation) was acquired with a Nikon camera with a 300 mm lens and a 2X extender (Method 3). Thirty-seven views of the external tank from Magazine 303 were received. The exposure is good on all frames. The focus is good on most frames. Timing data is present on the film. The first picture was taken on July 13, 1995 at 13:55:19 UTC (approximately 13 minutes after liftoff) and the last picture was taken at 14:03:43 UTC.

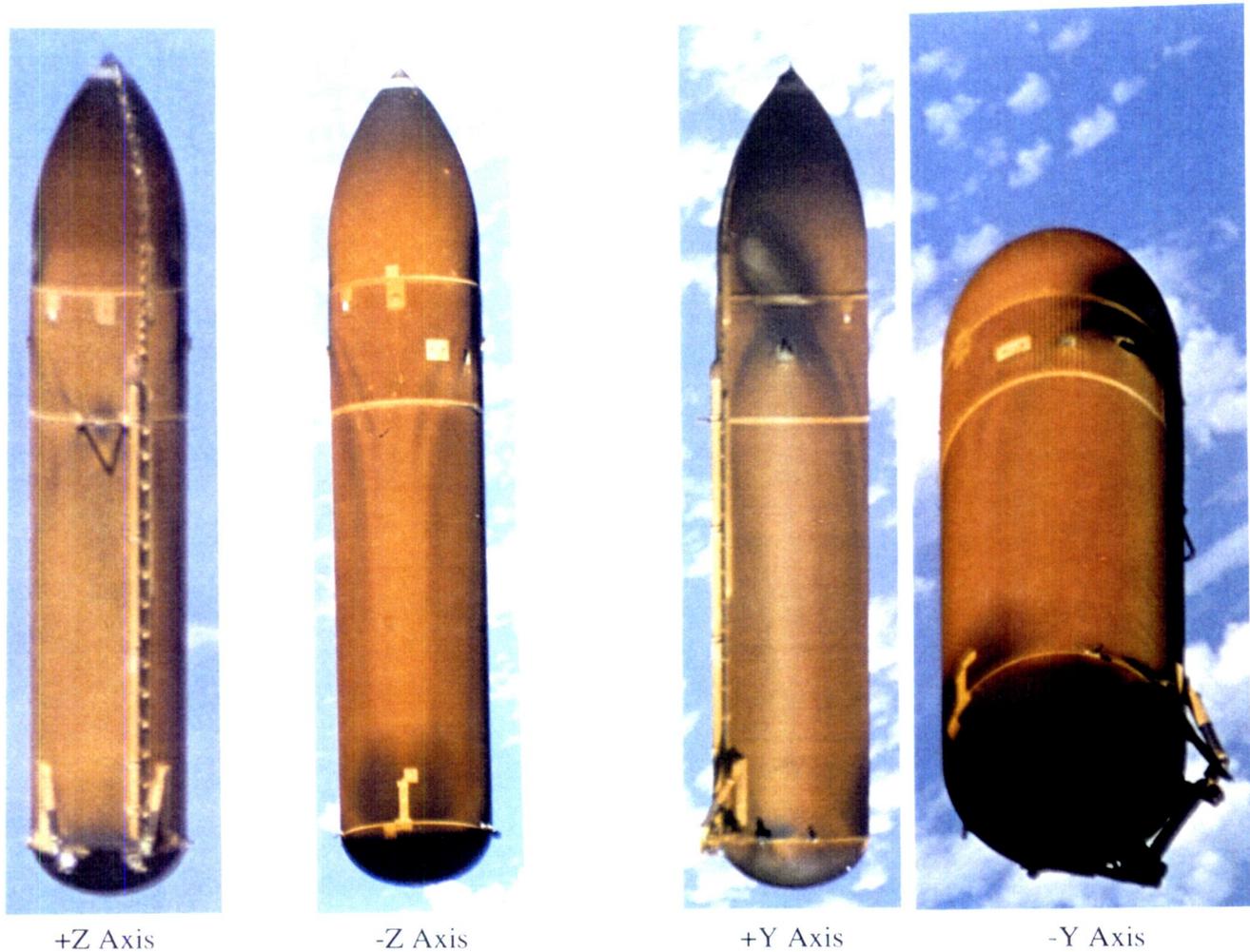


Figure 2.4.1 Handheld Photography of the External Tank

All aspects of the external tank (ET) were imaged (Figure 2.4.1). The external tank appeared to be in excellent condition. No anomalies were noted. The normal aeroheating marks and Booster Separation Motor burn scars are visible. Other marks visible on the external tank TPS were verified by KSC to be the repairs made prior to launch (woodpecker damage). These repairs appeared to be intact.

1. STS-70 (OV-103): Film/Video Screening and Timing Summary

2.5 LANDING EVENTS

2.5.1 Landing Sink Rate Analysis (Task #3)

The main gear sink rate of the Orbiter was determined over a one second time period prior to main gear touchdown. Also, the nose gear sink rate was determined over a one second time period prior to the nose gear touchdown.

The measured main gear and nose gear sink rate values were found to be below the maximum allowable values of 9.6 ft/sec for a 211,000 lb. vehicle and 6.0 ft/sec for a 240,000 lb. vehicle (the landing weight of the STS-70 Orbiter was reported to be 195,800 lbs.). The sink rate measurements for STS-70 are given in Table 2.5.1. In Figures 2.5.1. and 2.5.2. the trend of the measured data points for both film camera image data and video image data are illustrated.

Prior to Touchdown (1 sec)	Sink Rate: Film	Sink Rate: Video
Main Gear	1.40 ft/sec	1.38 ft/sec
Nose Gear	3.96 ft/sec	4.14 ft/sec

Table 2.5.1: Sink Rate Measurements

1. STS-70 (OV-103): Film/Video Screening and Timing Summary

STS-70 Main Gear Sink Rate

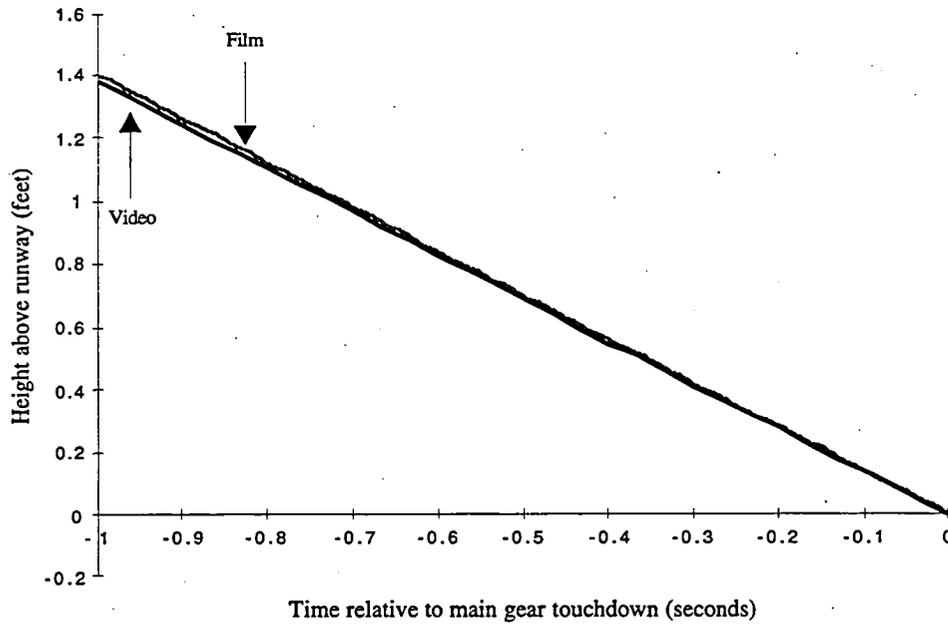


Figure 2.5.1 (A): Main Gear Sink Rate from Film (EL9) and Video (Runway South) (Shown as Trend of Data Points)

STS-70 Nose Gear Sink Rate

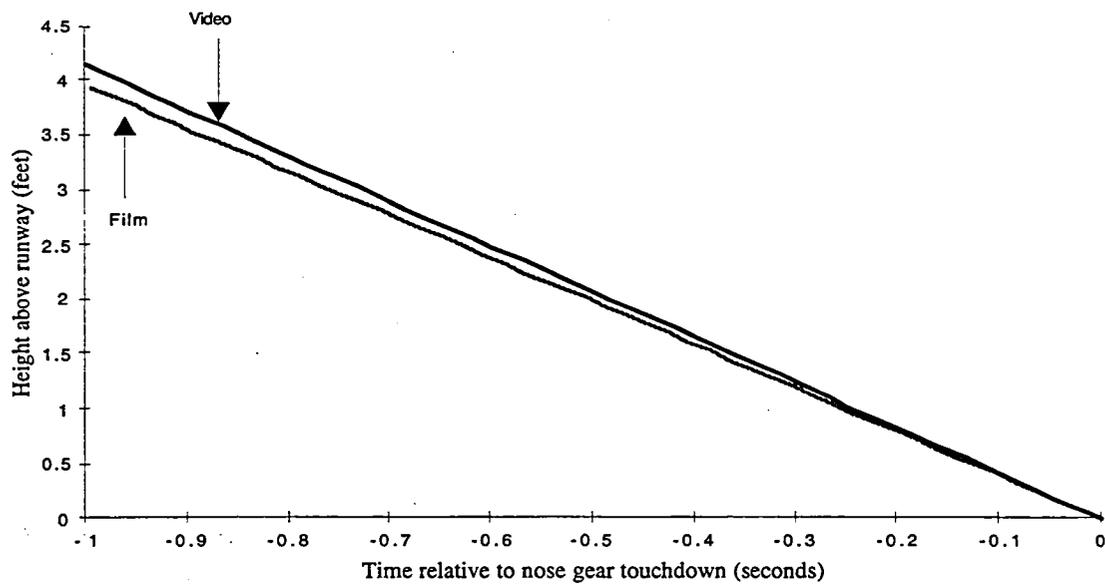


Figure 2.5.1 (B): Nose Gear Sink Rate from Film (EL15) and Video (KTV33L) (Shown as Trend of Data Points)

1. STS-70 (OV-103): Film/Video Screening and Timing Summary

2.5.2 Orbiter Height above Threshold (Task #13)

The Orbiter height above threshold for STS-70 was measured to be a distance of 23.0 feet between the bottom of the main gear tire and the runway surface as the Orbiter passed over the runway threshold during final approach. The image resolution and photogrammetric error considerations indicate an error of +/- 4 inches for this measurement.

2.6 OTHER

2.6.1 Normal Events

Other normal events observed include: ice buildup on the SSME vent nozzles, normal SSME ignition sequence, RCS paper debris at SSME ignition, left inboard and outboard elevon motion at SSME ignition, debris on/near the MLP during SSME start-up through liftoff, slight vapor from the gaseous oxygen (GOX) vent on the ET, frost on the ET vent louvers, ET twang, overshoot of the roll maneuver, slight vertical stabilizer motion at liftoff, contrails from the Orbiter wing tips after liftoff, acoustic waves at liftoff, bird in the vicinity of the Shuttle Launch Vehicle at liftoff, RCS paper after liftoff, ET aft dome outgassing after liftoff, slight body flap motion after the roll maneuver, SRB plume brightening, and SRB separation.

Normal events seen that are related to the pad are hydrogen ignitor operation, fixed service structure (FSS) deluge water spray activation, GH2 vent arm retraction, hydrogen burn ignitor operation, sound suppression water initiation, mobile launch platform (MLP) water dump activation, and LH2 TSM door closure.

APPENDIX B. MSFC PHOTOGRAPHIC ANALYSIS SUMMARY



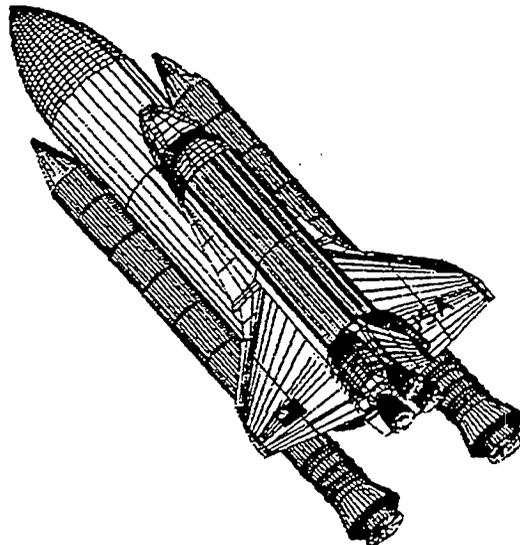
National Aeronautics and
Space Administration

George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama 35812

SPACE SHUTTLE

ENGINEERING PHOTOGRAPHIC ANALYSIS REPORT

STS-70



ENGINEERING PHOTOGRAPHIC ANALYSIS REPORT

STS-70

FINAL

PREPARED BY:

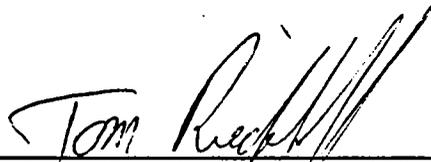
M. COVAN, J. HIXSON
PHOTOGRAPHIC ANALYSIS/ROCKWELL/HSV

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STS-70 ENGINEERING PHOTOGRAPHIC ANALYSIS REPORT

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July 27, 1995

I. INTRODUCTION

The launch of space shuttle mission STS-70, the twenty-first flight of the Orbiter Discovery occurred on July 13, 1995, at approximately 9:42 A.M. Central Daylight Time from Launch Complex 39B (LC-39B), Kennedy Space Center (KSC), Florida.

Extensive photographic and video coverage exists and has been evaluated to determine proper operation of the ground and flight hardware. Cameras (video and cine) providing this coverage are located on the fixed service structure (FSS), mobile launch platform (MLP), LC-39B perimeter sites, onboard the vehicle, and uprange and downrange tracking sites.

II. ENGINEERING ANALYSIS OBJECTIVES:

The planned engineering photographic and video analysis objectives for STS-70 included, but were not limited to the following:

- a. Overall facility and shuttle vehicle coverage for anomaly detection
- b. Determination of SRB PIC firing time and SRB separation time
- c. Verification of Thermal Protection System (TPS) integrity
- d. Correct operation of the following:
 1. SSME ignition
 2. SRB debris containment system
 3. LH2 and LO2 17" disconnects
 4. Ground umbilical carrier plate (GUCP)
 5. Free hydrogen ignitors
 6. Booster separation motors (BSM)
 7. Vehicle clearances
 8. Vehicle motion
- e. Verification of cameras, lighting and timing systems

III. CAMERA COVERAGE ASSESSMENT:

Film was received from fifty-one of fifty-one requested cameras as well as video from twenty-four of twenty-four requested cameras. The following table illustrates the camera data received at MSFC for STS-70.

**Camera data received at MSFC
for STS-70**

	16mm	35mm	Video
MLP	22	0	4
FSS	7	0	3
Perimeter	3	3	6
Tracking	0	15	10
Onboard	0	1	0
Totals	32	19	23
Total number of films and videos received:			74

The individual motion picture and video camera assessments are available on the Engineering Photographic Analysis server on the World Wide Web. The server address is <http://photo4.msfc.nasa.gov/msfc.html>

a. Ground Camera Coverage:

All ground cameras operated properly with the exception of a few minor problems. Camera E-222 does not have valid timing and camera E-212 experienced mechanical difficulty resulting in a short film run. Camera E-213 experienced a tracking problem. Some tracking items were obscured by clouds.

b. Onboard Camera Coverage:

Thirty-seven frames of the external tank were imaged by the astronauts using the hand-held camera. All sides of the tank were imaged. The photographs were of excellent quality.

IV. ANOMALIES/OBSERVATIONS:

No anomalies or issues were detected. However, several of the typical events noted on most missions were observed. These include ice/frost from the 17" disconnects at SSME ignition and liftoff, pad debris, loose thermal curatin tape and small debris particles such as butcher paper and purge barrier material falling aft of the vehicle during ascent. No TPS divots on the external tank were noted after separation from the on-board hand-held camera film.

White vapors were observed venting from the ET intertank aero vent (+Z) during SSME start and liftoff. Five pulses of vapors were observed during this time. Figure one is a film frame from camera E-34 showing one of the pulses. This type of venting was last observed on STS-51.

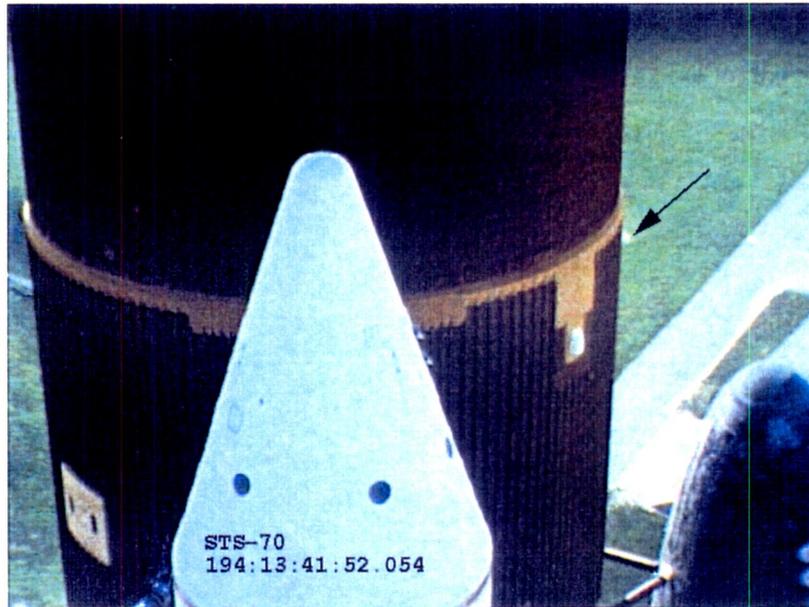


Figure 1 White vapors from ET aero vent

A large piece of instafoam remained attached to the right SRB aft skirt purge line at liftoff. Figure two shows this piece and the resulting divot at the base of the aft skirt instafoam. This piece was subsequently broken into several small pieces by the plume.

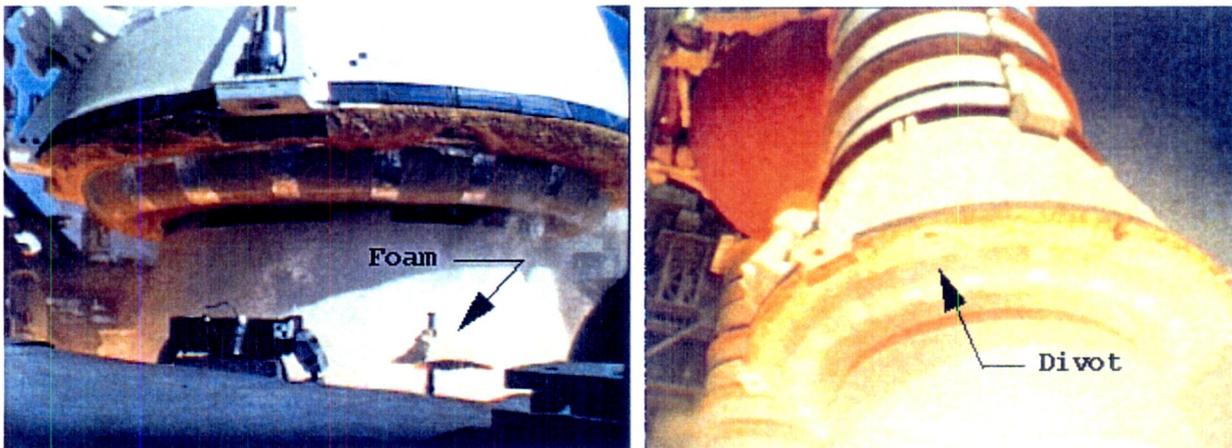


Figure 2 Instafoam on purge line and resulting divot

Two pieces of water baggie material were observed rising from the SRB flame bucket and striking the LO2 TSM and falling back into the flame bucket at liftoff. Figure three shows this event as recorded by camera E-34.



Figure 3 Water baggie material

Two small pieces of debris were observed between the Orbiter belly and the ET during liftoff from camera E-34. Neither piece of debris appears to strike the vehicle. These particles are typically frost from the LO2 feed-line forward bellows.

A debris induced streak in the SSME plume was observed on film from camera E-222 during ascent and is shown in Figure four. No time information is available.

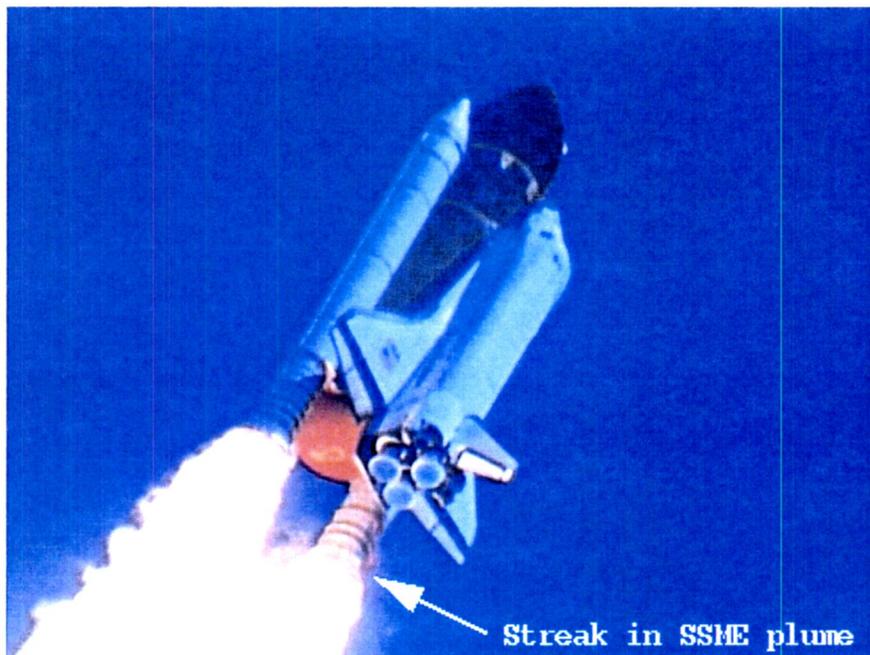


Figure 4 Debris induced streak in SSME plume

A pronounced condensation collar was visible around the vehicle during ascent between 44 and 57 seconds MET. Figure five shows this event from camera E-222. This type of event is attributed to unique atmospheric conditions.

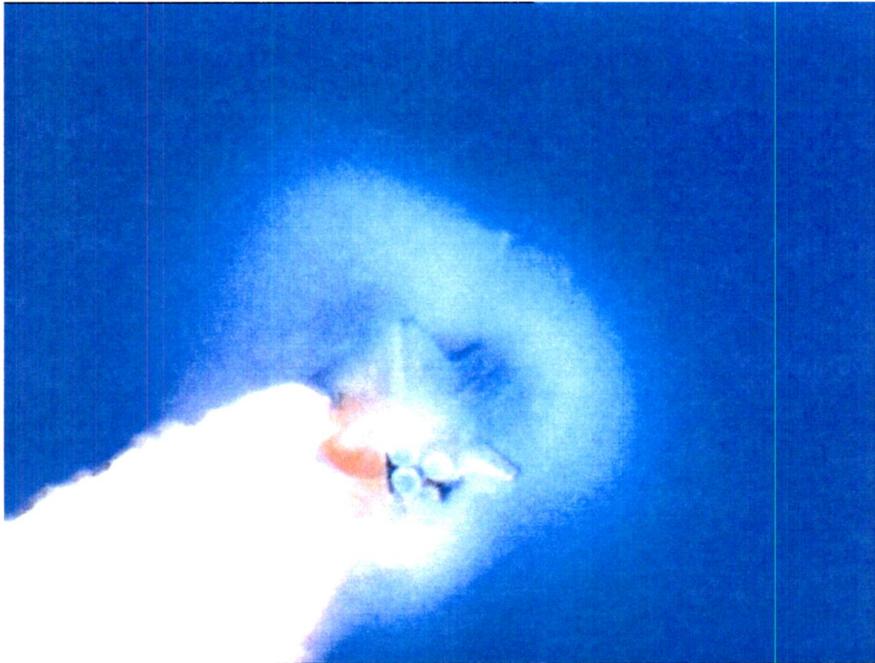


Figure 5 Condensation collar around vehicle

V. ENGINEERING DATA RESULTS:

a. T-Zero Times:

T-Zero times are determined from cameras that view the SRB holddown posts numbers M-1, M-2, M-5 and M-6. These cameras record the explosive bolt combustion products.

HOLDDOWN POST	CAMERA POSITION	TIME (UTC)
M-1	E-9	194:13:41:55.030
M-2	E-8	194:13:41:55.029
M-5	E-12	194:13:41:55.029
M-6	E-13	194:13:41:55.030

b. ET Tip Deflection:

Maximum ET tip deflection for this mission was measured at 31.5 inches. Figure six is a data plot showing the measured motion of the ET tip in both the horizontal and vertical directions. A positive horizontal displacement represents motion in the -Z direction. These data were derived from film camera E-79.

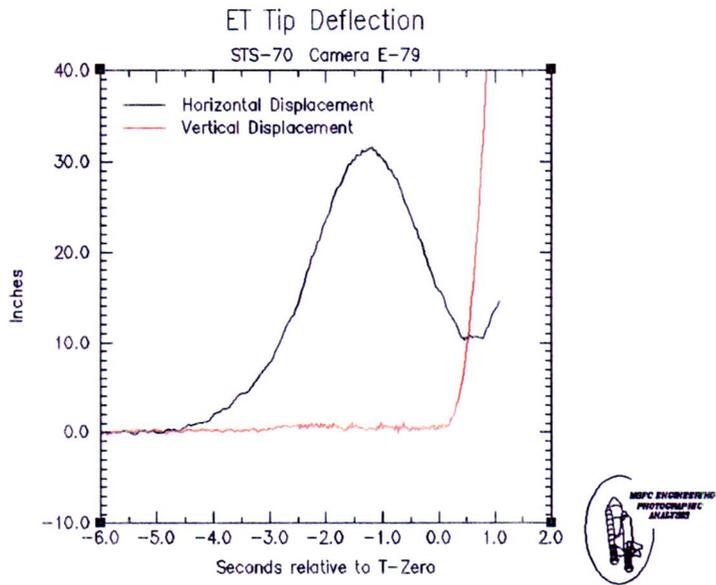


Figure 6 ET tip deflection

c. SRB Separation Time:

SRB separation time for STS-70 was determined to be 194:13:43:57.79 UTC as recorded by tracking camera E-207.

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1. AGENCY USE ONLY (Leave blank)		2. REPORT DATE September 1995	3. REPORT TYPE AND DATES COVERED Final 12 July - 24 July 1995	
4. TITLE AND SUBTITLE Debris/Ice/TPS Assessment and Integrated Photographic Analysis of Shuttle Mission STS-70			5. FUNDING NUMBERS	
6. AUTHOR(S) Gregory N. Katnik Barry C. Bowen J. Bradley Davis				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) NASA ET/SRB Mechanical Systems Mail Code: TV-MSD-7 Kennedy Space Center, Florida 32899			8. PERFORMING ORGANIZATION REPORT NUMBER TM 95-110857	
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)			10. SPONSORING / MONITORING AGENCY REPORT NUMBER	
11. SUPPLEMENTARY NOTES				
12a. DISTRIBUTION / AVAILABILITY STATEMENT Publicly Available Unclassified - Unlimited			12b. DISTRIBUTION CODE	
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			16. PRICE CODE	
17. SECURITY CLASSIFICATION OF REPORT Unclassified	18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified	19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified	20. LIMITATION OF ABSTRACT Unlimited	

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